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National Aeronautics and Space Administration

Electronic Components and Circuits

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01-02 February 2001

INTRODUCTION

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NASA TechBriefs

National Aeronautics and Space Administration

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Electronic Components and Circuits

Hardware, Techniques, and Processes

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Reconfigurable Arrays of Transistors for Evolvable Hardware

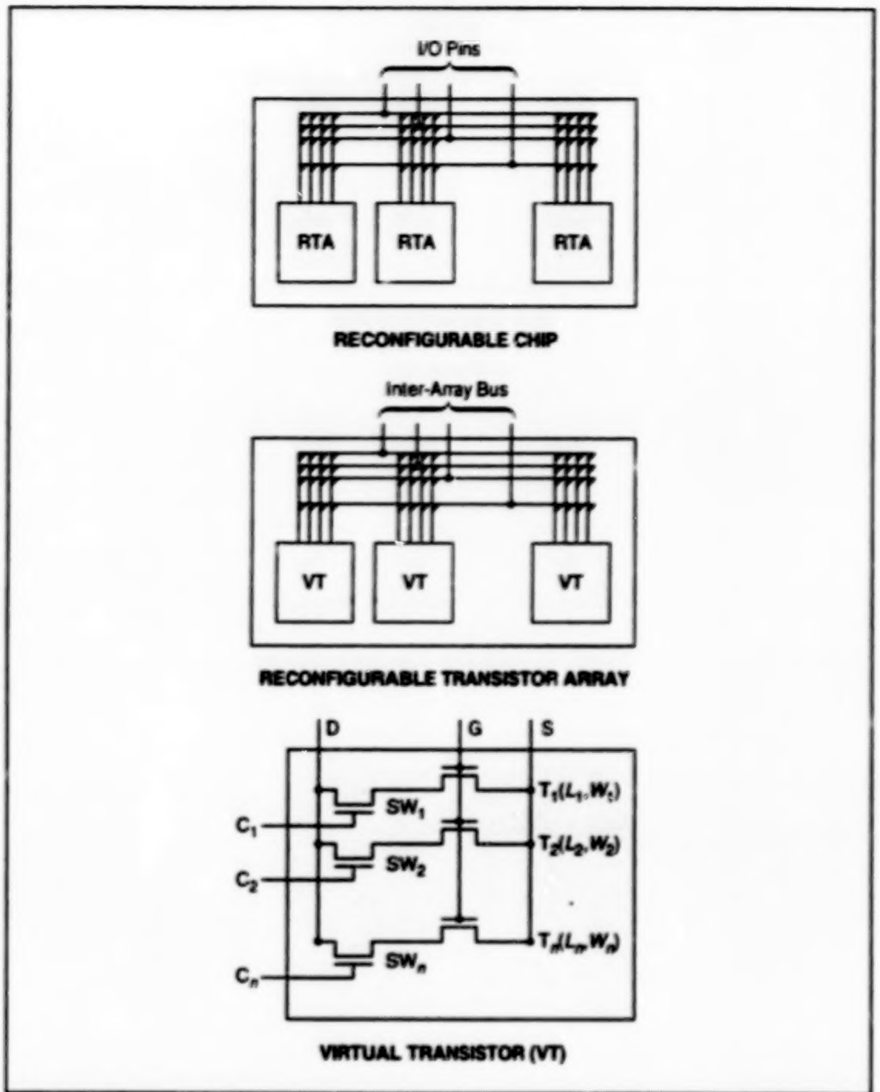
Transistors in hierarchical arrays would be connected according to hierarchical control signals.

NASA's Jet Propulsion Laboratory, Pasadena, California

Very-large-scale integrated (VLSI) circuits containing electronically reconfigurable arrays of transistors have been proposed as means to implement a forthcoming generation of a special class of digital/analog electronic circuits. The class in question is a subclass of advanced electronic and other equipment of a type called "evolvable hardware" (EHW). The major distinguishing feature of EHW is that under the direction of genetic and/or other evolutionary algorithms, its configuration and thus its functionality can be made to evolve until it exhibits a desired behavior or adapts to the environment in a prescribed way. An EHW system is said to be extrinsic if its evolution is directed and evaluated by a computer or other external system. An EHW system is said to be intrinsic if it includes an electronic or other subsystem that automatically directs and evaluates its evolution.

The evolution of an EHW system includes selective, repetitive reconfiguration of a set of available resources and/or the addition of building blocks. In the case of electronic EHW, such reconfiguration typically involves the connection or disconnection of transistors, amplifiers, inverters, and/or other circuit building blocks in an array of such building blocks. One example of electronic EHW is a programmable logic device (PLD), which contains logic-circuit building blocks. A pattern of interconnections among the building blocks can be downloaded to configure the PLD to perform desired logic functions. In some PLDs, the interconnection patterns are established by irreversible means; in most others, interconnection patterns can be changed reversibly by coupling appropriate signals to designated electronic (e.g., transistor) switches.

A VLSI circuit of the type proposed would be fabricated in complementary metal oxide/semiconductor (CMOS). It would contain hierarchical arrays and subarrays of transistors (see figure). Each subarray at the lowest level of the hierarchy would contain transistors T_i (i = 1 through n), each with a different combination of channel length and width (L_i and W_i, respectively). The sources and gates of all n transistors in the subarray would be connected to a common source (S) and a common gate (G) line, respectively. The gate of the ith transistor could optionally be connected to a common drain (D) line via an analog transistor switch SW_i by applying the corresponding control signal C_i.



Transistors in Groups of *n* would be selectively connected to form VTs, which would be selectively connected into RTAs, and so forth up the hierarchy.

Various combinations of electrical parameters would be associated with the various channel lengths and widths. Thus, one could choose one or more control signal(s) to connect one or more of the transistors T_i to make the subarray behave as though it were a single transistor [denoted a "virtual transistor" (VT)] with a desired analog or digital electrical behavior.

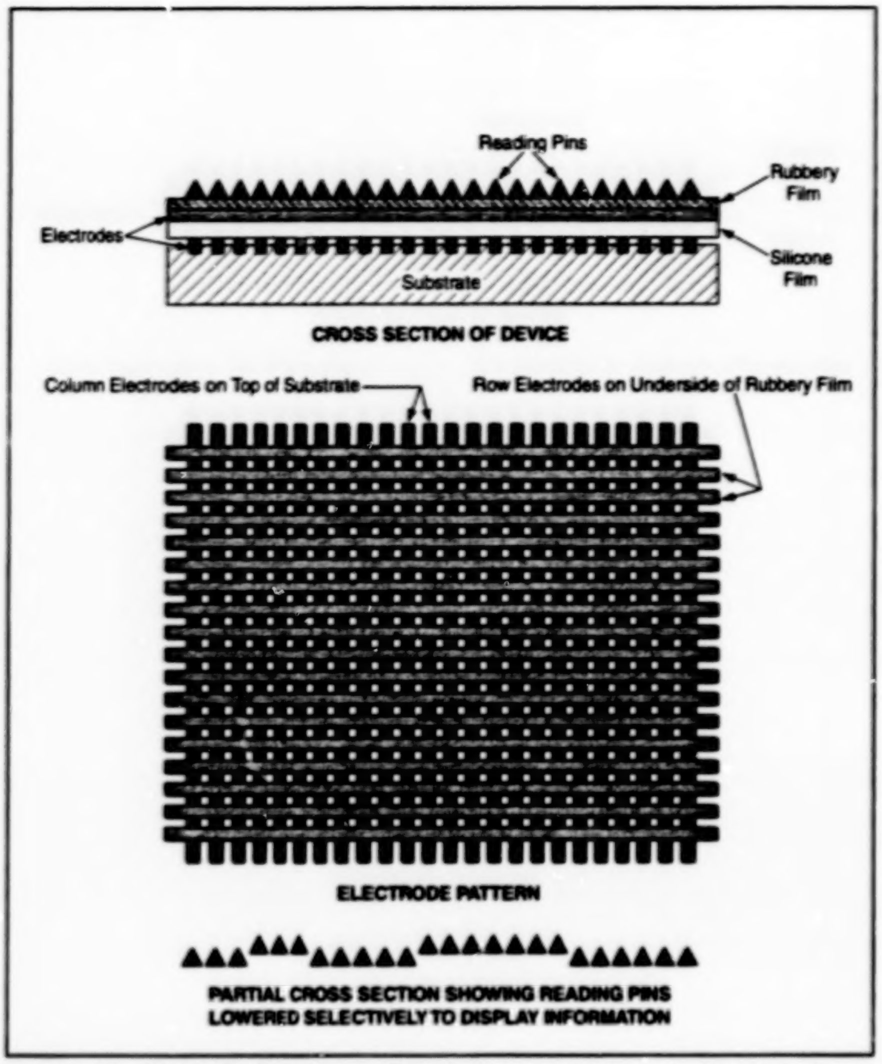
The VTs would be grouped into reconfigurable transistor arrays (RTAs), linked by inter-array buses. The RTAs could be similarly clustered on the chip with a bus connected to input/output (I/O) pins; alternatively, the hierarchy could be extended to one or more additional levels, ending in I/O pins at the highest level. The connections at the various levels of the hierarchy would be governed by a corresponding hierarchy of on/off control signals, ending in the previously mentioned control signals C_i at the lowest (transistor) level. With respect to a genetic algorithm for evolution of the overall configuration of circuitry on the VLSI chip, the portion of this hierarchy that ended at each transistor could be regarded as a chromosome fragment containing the genetic information for that transistor.

This work was done by Adrian Stoica of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP* *[see page 1].*
NPO-20078

Active Tactile Display Device for Reading by a Blind Person

Heights of numerous pins would be varied to form patterns that could be felt.

NASA's Jet Propulsion Laboratory, Pasadena, California



Reading Pins Would Be Pulled Down Selectively by electrostriction in the silicone film at intersections between selected row and column electrodes to which a voltage would be applied.

A proposed active tactile display device would present textual and graphical information to a blind person. The concept of this device is a byproduct of recent research on the use of electroactive polymers to generate forces and displacements in novel robotic actuators.

The display medium would be a planar array of small cones called "reading pins" (see figure). Under computer control, reading pins would be lowered individually or in groups to produce a tactile pattern of highs and lows representing the information to be read. A person would read the pattern by scanning with fingertips, as in reading conventional Braille print.

The pins would be lowered by use of an electroactive polymer; specifically, a silicone that, in film form, has been found to contract by as much as 30 percent when subjected to an electric field. The reading pins would be mounted on an electrically insulating rubbery film on top of a silicone film on top of a rigid, highly electrically resistive substrate.

A given reading pin would be lowered by applying a voltage across the thickness of the silicone film at the location directly under the pin. Electrodes to apply voltages at such locations would be formed on the top and bottom surfaces of the silicone film. The electrodes on each surface would be evenly spaced, parallel metal film strips, and the top and bottom electrode arrays would be crossed to obtain a square grid corresponding to the locations of pins to be lowered. The electrode films would be formed before assembling the layers by sputtering, onto the substrate and onto the rubbery sheet, a layer of chromium 50 Å thick followed by a gold layer 1,500 to 2,500 Å thick. The electrode films would be formed into the required patterns by photolithography or ink printing techniques.

Because the actuated pins would be pulled down, the information to be displayed would have to be formatted analogously to an image on negative film; for example, ridges representing lines in an image would be formed by pulling down pins to form valleys between the ridges. The resolution of the display could be selected by choosing the pixel widths of letters, numbers, and other characters.

This work was done by Yoseph Bar-Cohen of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
NPO-20410

Rechargeable Batteries Based on Intercalation in Graphite

Batteries could be recharged thermally or electrically.

NASA's Jet Propulsion Laboratory, Pasadena, California

Storage batteries based on intercalation of lithium and bromine in graphite have been proposed. Like other storage batteries, these could be recharged electrically. Optionally, these batteries could also be recharged thermally at relatively low temperatures — by use of solar or waste heat, for example. In comparison with thermocouples and thermionic devices, the proposed batteries would generate much greater potentials (about 4 V per cell versus millivolts per thermocouple or thermionic device) and would convert heat to electricity with greater efficiencies.

A cell in a battery of this type would

include a graphite anode and a graphite cathode surrounded by lithium bromide dissolved in a nonaqueous solvent like diethyl carbonate, dimethyl carbonate, dioxane, propylene carbonate, ethylene carbonate, or a mixture of two or more of these compounds. The two electrodes would be separated by an ion-exchange membrane impermeable to bromine [or Br_3^- ions (see Figure 1)]. It is known from prior research that graphite forms intercalation compounds with halogens and with alkali metals. It is also known from prior research that intercalation of a halogen (in this case, bromine) leads to a positive charge on the graphite and negative charge on the halogen atoms, while intercalation of alkali metal (in this case, lithium) leads to a negative charge on the graphite and positive charge on the alkali metal atoms.

In the fully charged state, the anode would be loaded with lithium, and there would be free liquid bromine in the compartment surrounding the cathode. During discharge, bromine would become intercalated into the cathode, while lithium would come out of the anode. At the end of the discharge, the anode would not contain an appreciable amount of lithium, while the cathode would contain the intercalation compound CBr_x. The discharge processes at the anode and cathode could be driven electrically in reverse to charge the cell in the customary way.

The expectation that one could also recharge the cell thermally is based on the observed temperature dependence of the intercalation of bromine in graphite. Figure 2 illustrates the results of an experiment in which most of the bromine previously intercalated in a graphite specimen was driven out by heating to a temperature of 120 °C. To utilize this phenomenon to recharge the cell, one would first make an external electrical connection between the cathode and anode, then heat the cathode to drive out the bromine. The resultant electrical current through the external connection would cause lithium to become intercalated into the cathode. One would then break the external electrical connection, then allow the cathode to cool to ambient temperature, at which point the cell would be ready for discharge.

Also, during the process of thermal recharging, a voltage equal and opposite to the reversible potential of the cell must be included in the charging circuit in order to enable recharge. If such a voltage is provided by another cell of the same type, then such a two-cell system will operate as a thermally regenerative device with one cell being charged and the other undergoing discharge. The cell undergoing charge would be kept at a higher temperature compared to the cell being discharged.

This work was done by Pramod K. Sharma, Sekharipuram Narayanan, and Gregory S. Hickey of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

This invention has been patented by NASA (U.S. Patent No. 6,042,964). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL [see page 1]. Refer to NPO-19824.

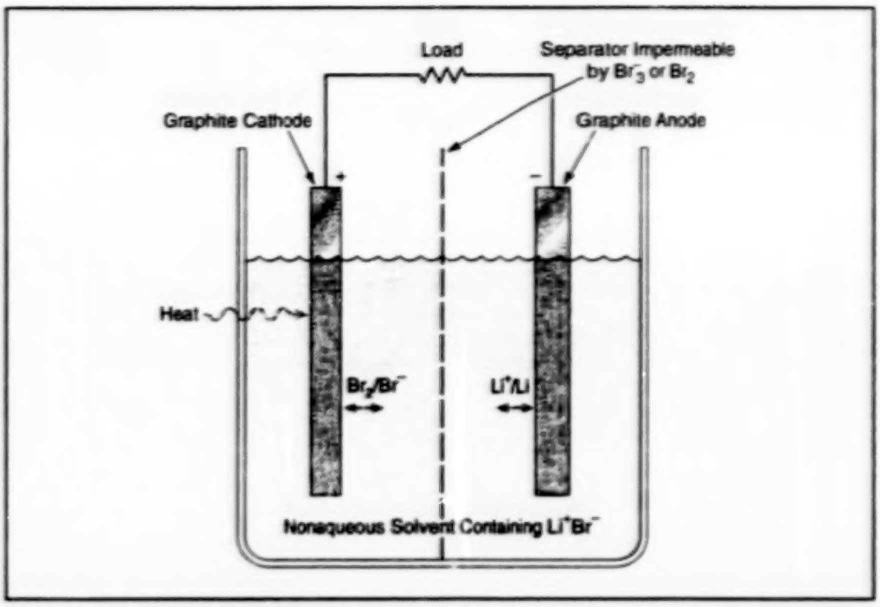


Figure 1. This **Rechargeable Electrochemical Cell** would exploit the reversible intercalation of lithium and bromine in graphite.

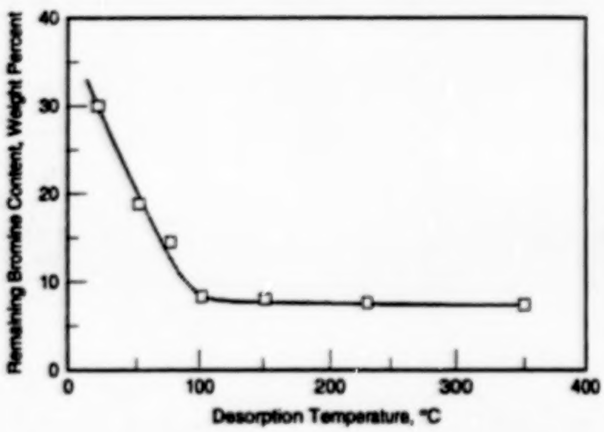


Figure 2. The **Desorption of Bromine** from a specimen of bromine-treated graphite was measured while the specimen was heated to progressively higher temperatures in vacuum.

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Electronic Systems

Hardware, Techniques, and Processes

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Inertial/GPS Pointing and Positioning System

This system operates independently of the moving platform that carries the instrument.

Ames Research Center, Moffett Field, California

A data system generates information on the position and orientation of a pointing instrument (e.g., a telescope or a laser) that could be mounted on a moving platform (e.g., an aircraft) and generates platform-steering commands for pointing the instrument at a known target (e.g., a target on the ground, a celestial body, or an artificial satellite). The subsystems of this system include an inertial navigation system (INS) and a Global Positioning System (GPS) antenna and receiver.

Unlike other instrument-pointing systems, the INS mounts directly on the pointing instrument instead of on the platform. As a result, the INS decouples from the platform in the sense that it determines the position and orientation of the instrument independently of the platform. In further contradistinction to other instrument-pointing systems, the pointing instrument is not slaved to the platform; instead, as explained below, the platform is slaved to the pointing instrument and the INS.

The position and orientation of the INS relative to the pointing instrument are known and remain fixed, unlike in other systems, in which INSs are located elsewhere and it is necessary to measure suspension angles and to utilize multiple platform and suspension coordinate transformations subject to buildup of platform-bending and misalignment errors. The direct-mounting scheme thus eliminates several sources of instrument-pointing error and simplifies design and operation (thereby also reducing cost).

The INS contains triads of gyroscopes and accelerometers and associated analog and digital electronic circuits. The GPS antenna and receiver are mounted on the pointing instrument along with the INS. The GPS signals are used to correct drift errors in the INS position and orientation outputs. The position and orientation data (including GPS corrections) from the INS are sent to a computer, along with GPS time data. The computer selects the relevant data and processes these data through a series of transformation routines to generate command angles or instructions, in a preferred navigation coordinate frame, for pointing the instrument at a known stationary or moving target.

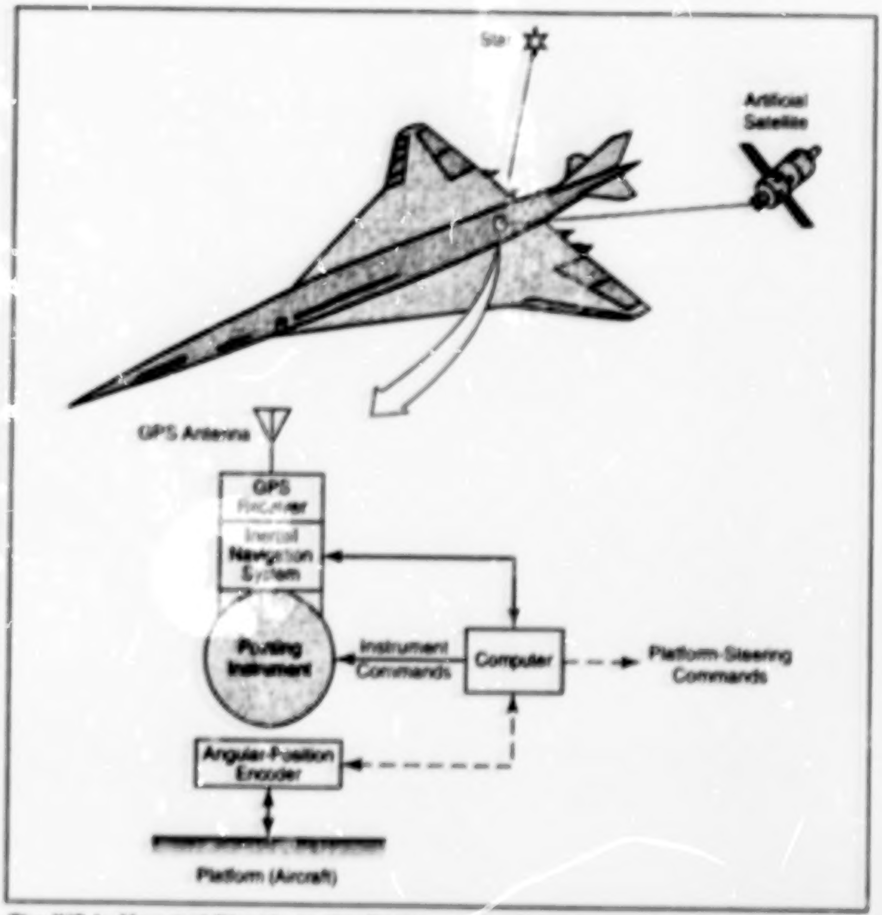
The computer calculates the required instrument-pointing angles in the navigation coordinate frame. The computer then compares the required instrument-pointing angles with the actual instrument-pointing angles determined by the INS. Next, using control logic, the computer processes the results of this comparison into corrected pointing angle commands. It is desirable to keep the corrected pointing angle commands as close to zero as possible. These commands are used for fine pointing of the instrument as the platform moves.

In some applications, steering instructions from this system are used for navigating the platform. In such an application, an angular-position encoder provides data on the orientation of the platform relative to the instrument. The encoder may, if necessary, be far less accurate than the encoders used in other instrument-pointing and navigation system; its accuracy need not exceed that of the platform autopilot or steering control subsystem.

In normal operation with respect to a celestial target viewed from an aircraft, an operator first gives the computer the celestial coordinates (e.g., right ascension and declination) of the target. The computer then generates a command to steer the aircraft onto a heading that will enable the instrument to acquire the target. The heading command can be routed to the autopilot. Once the aircraft is on the desired heading, the computer commands the pointing instrument to turn to the required elevation, azimuth, and line-of-sight angles for tracking the target.

This work was done by Robert Yee and Fred Robbins of **Ames Research Center**. *Further information is contained in a TSP [see page 1].*

This invention has been patented by NASA (U.S. Patent No. 5,809,457). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14060.

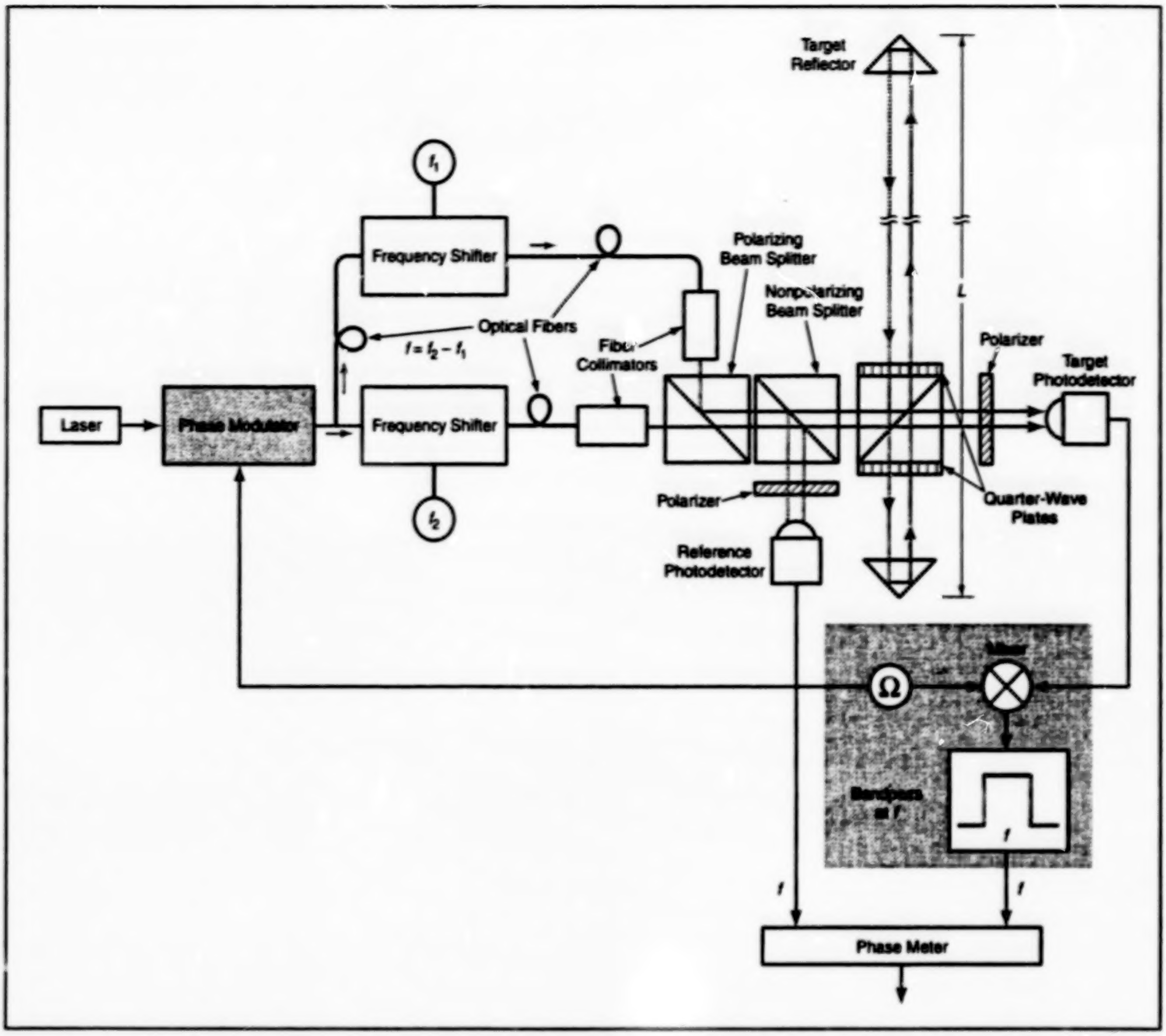


The INS Is Mounted Directly on the Pointing Instrument instead of on the platform as in other systems. This direct-mounting scheme affords the advantages of less complexity, greater accuracy, and lower cost, relative to other instrument-pointing systems.

Heterodyne Interferometer With Phase-Modulated Carrier

Resolution and working distance are increased.

NASA's Jet Propulsion Laboratory, Pasadena, California



This **Heterodyne Optical Interferometer** is augmented to suppress self-interference. The augmentation consists in the addition of the shaded parts.

A heterodyne optical interferometer of a type used to measure small displacements can be augmented to suppress a phenomenon, called "self-interference," that tends to limit the achievable resolution and working distance and can even render the interferometer inoperable. The technique for suppressing self-interference can be implemented by use of commercial off-the-shelf optoelectronic and electro-optical components, and does not degrade the fundamental operation of the interferometer.

Self-interference is caused by optical scattering, imperfections in optical surfaces, and misalignment of optical components. Like many other optical interferometers, an interferometer of this type includes a target and a reference optical path. Self-interference typically manifests itself as leakage, along the reference path, of part of the optical signal power intended to propagate solely along the target path. This leakage, in turn, manifests itself as a heterodyne signal with the incorrect phase that competes against the heterodyne signal with the correct phase.

The figure schematically depicts a heterodyne interferometer configured for measuring a target path of length L. This interferometer is augmented to suppress self-interference by using phase modulation to distinguish between the leaked signal and the signal returning from the target. The following is a summary of the self-interference-suppression technique, omitting some details for the sake of brevity:

The optical carrier wave (that is, the beam coming out of the laser) is phase modulated at an angular frequency Ω before it is sent along the two paths of the interferometer. The phase modulation, by itself, is invisible to the photodetectors at the reference and target photodetectors unless it is converted, by the phase delay of one path of the interferometer relative to the other, to intensity modulation at the modulation angular frequency Ω. The self-interference signal is associated with light that does not go to the target and thus does not undergo

the differential delay that would give rise to this intensity modulation.

The "good" signal is associated with the optical beam that goes to the target and thus does undergo the differential delay that gives rise to intensity modulated at angular frequency Ω. Thus, demodulation by mixing with the oscillator signal at angular frequency Ω results in discrimination against all but the "good" signal.

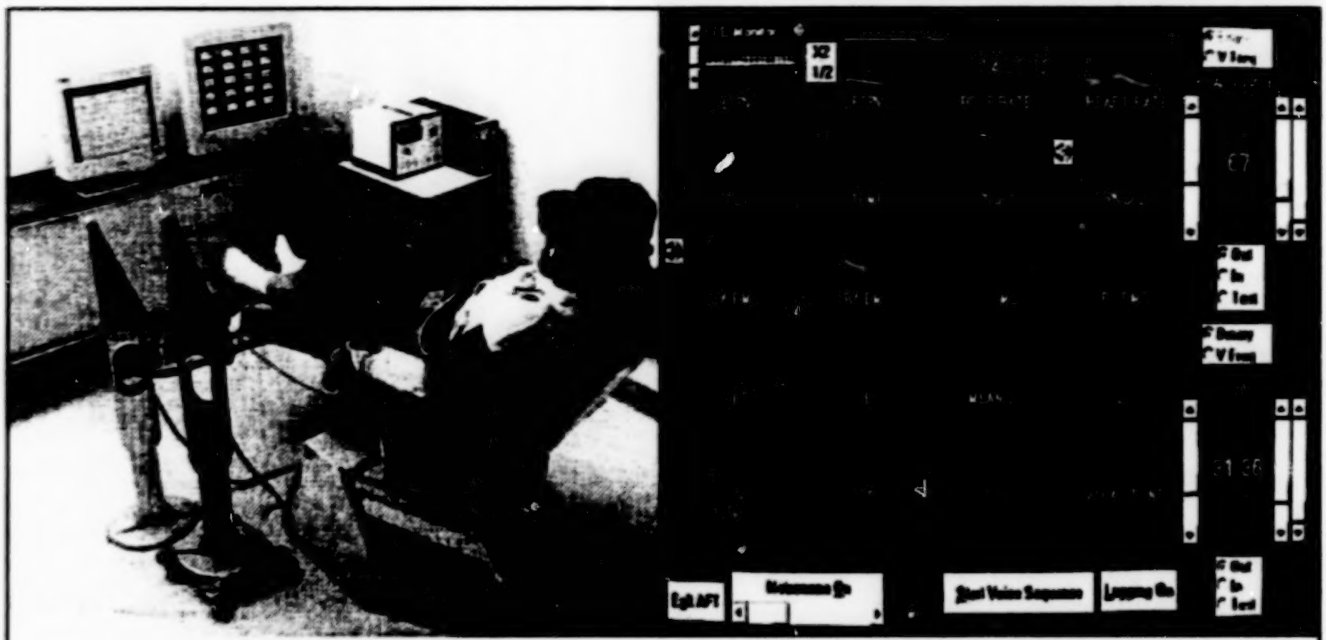
This work was done by Serge Dubovitsky of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL [see page 1]. Refer to NPO-20740.

A Personal-Computer-Based Physiological Training System

This system is an improved means of implementing autogenic-feedback training exercise.

Ames Research Center, Moffett Field, California



Subject Viewing Displays | **Close-Up View of Displays**

A Human Subject Receives Feedback by viewing display screens during AFTE.

The Autogenic Clinical/Lab System (ACLS) is a personal-computer-based instrumentation system for physiological training. This system can be used to implement a program of multiparameter physiological conditioning known as autogenic-feedback training exercise (AFTE).

Ground-based research to study the physiological effects of microgravity is dependent upon the acquisition and processing of physiological data. In the past, the real-time processing of these data has been difficult to achieve because of a need for dedicated instrumentation to calculate and display such derived variables as cardiac output, vascular resistance, thoracic fluid changes, and vagus-nerve activity. The dedicated instrumentation tends to be physically large (nonportable) and expensive (because of engineering input needed to design and build specific functions), and it is difficult to modify algorithms. However, by changing from a design approach based on dedicated instrumentation to one based on digital processing of physiological and other data in a Pentium/100 or similar computer, it has been possible to construct a physically smaller system (the ACLS) that costs less and can be modified more easily through changes in software.

In both the U.S. and Russian space programs, a great deal of effort is being spent studying the effects of long-term exposure to reduced gravitational fields. The objective is to develop effective countermeasures that will minimize the deleterious effects of microgravity on the human body. The approach used by NASA/Ames researchers involves the use of AFTE to eliminate or reduce space motion sickness and the dizziness that can occur when flight crews return to the gravitational effects of a terrestrial existence.

AFTE in its current form is a six-hour training program based on a highly efficient and effective training method of enabling people to control voluntarily several of their own physiological responses to a variety of environmental stressors. The AFTE approach has been successful in combating intractable airsickness in pilots, and for improving pilot performance during search and rescue missions. In clinical studies with patients, substantial relief from symptoms of nausea, syncope, and severe abdominal pain has been observed.

AFTE, as implemented by use of the ACLS, involves the real-time acquisition and display of 16 input variables, 20 digitally displayed output variables (see figure), and printed averages, plus the generation of coupled audible tones, voice commands, and respiratory pacing signals. The software for the ACLS was written for the Windows 98 operating system, using Microsoft Visual BASIC. This software combination was chosen because of the ease with which one can develop visual displays and user interfaces.

Analog data are collected by use of a commercial DI-200 data-acquisition board and WinDaq/200 data-acquisition software. Four video display adapters have been installed to enable the use of four video monitors on a single computer. The four monitors are configured to display various subsets of the available data, as follows: Each of monitors 1 and 2 makes as many as 16 channels of analog data available to the researcher and the subject; monitor 3 presents to the researcher digital meters of all calculated variables; and in effectuating part of the training process monitor 4 shows selected digital meters to the subject.

Audible tones, coupled to any two of 20 derived parameters, can be selected by the researcher and presented to the subject. The tones are generated on the internal sound card of the personal computer by use of software developed in the C computing language and implemented under Visual BASIC.

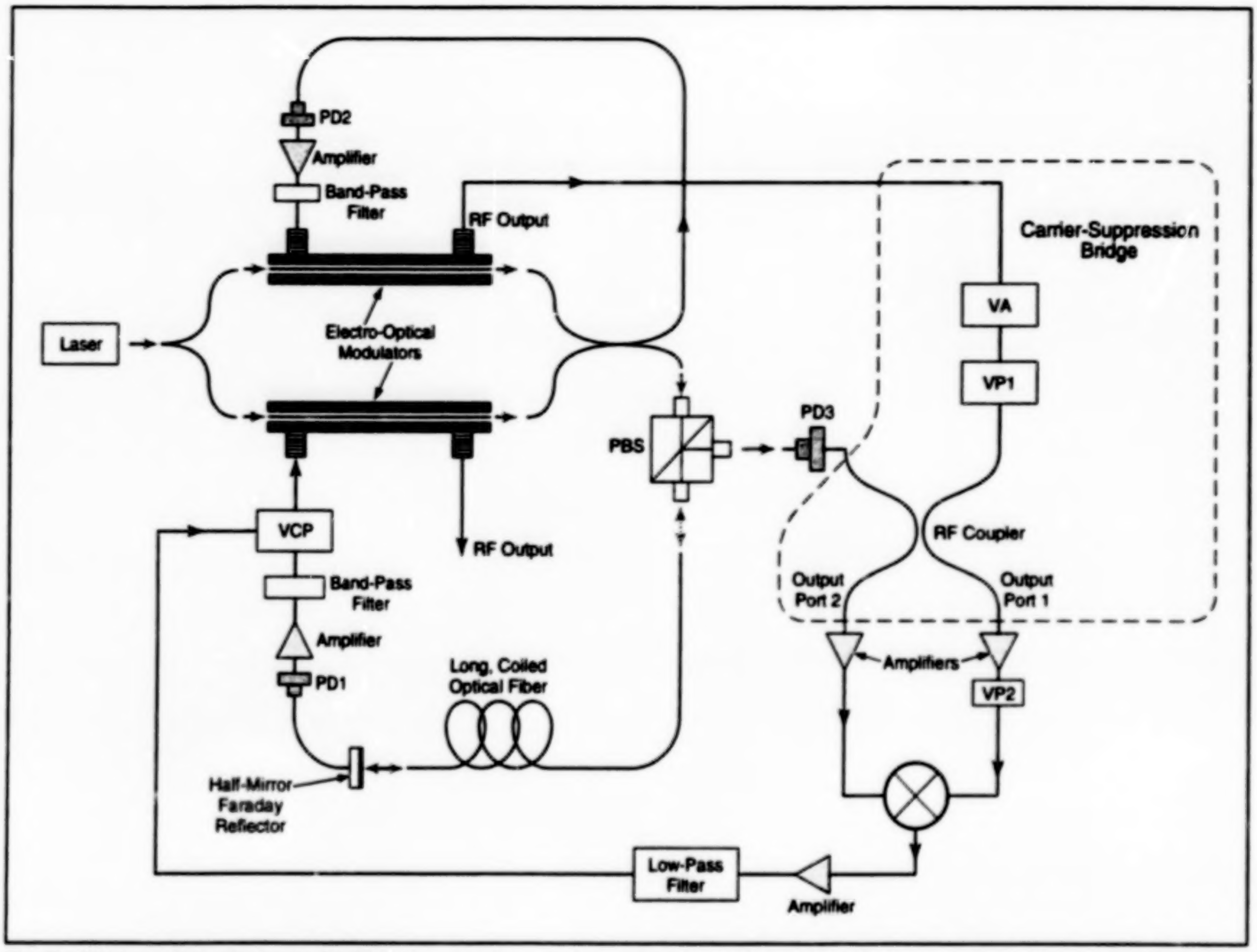
This work was done by Patricia Cowings, Bruce Taylor, and William Toscano of **Ames Research Center**. *Further information is contained in a TSP [see page 1].*

This invention has been patented by NASA (U.S. Patent No. 5,694,939). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14048-2.

OEOs With Carrier Suppression for Reduction of Phase Noise

A technique previously applied to microwave oscillators has been extended to OEOs.

NASA's Jet Propulsion Laboratory, Pasadena, California



This **Double-Loop Optoelectronic Oscillator** incorporates a carrier-suppression bridge, which acts, in conjunction with the long optical fiber, as a frequency discriminator to reduce frequency jitter and thus phase noise.

Optoelectronic oscillators (OEOs) that incorporate carrier-suppression subsystems for reduction of close-to-carrier phase noise are undergoing development. The carrier-suppression phase-noise-reduction technique has previously been applied to microwave oscillators. The close-to-carrier phase noise in a microwave oscillator consists mainly of a component that is generated in an amplifier in the oscillator feedback loop and that has a spectral amplitude proportional to $1/f$, where f is the difference between the frequency of interest and the carrier frequency. In the case of an OEO, one can use the carrier-suppression technique to reduce not only the component of phase noise generated in the amplifier but also the component of phase noise associated with laser relative-intensity noise.

The figure schematically depicts a dou-

ble-loop OEO with a carrier-suppression bridge for reduction of phase noise. The long oscillator loop includes a polarizing beam splitter (PBS), a long optical fiber wound into a coil, a half-mirror Faraday polarization rotator, a photodetector (PD1), a radio-frequency (RF) amplifier, a band-pass filter, a voltage-controlled phase shifter (VCP), and an electro-optical modulator. The short oscillator loop contains only a short optical fiber and does not include a VCP or a PBS.

The polarization of the light entering the PBS is adjusted so that all of this light passes through the PBS and into the long optical fiber. At the output end of the long optical fiber, part of the light passes through the Faraday half-mirror and travels on to PD1; another part of the light is reflected by the Faraday half-mirror with a polarization that, everywhere in the long optical fiber, is orthogonal to the polarization of the light traveling forward. The orthogonality minimizes the interaction between the forward-going and reflected light beams, thereby reducing noise.

The carrier-suppression bridge functions as follows: The reflected light in the long oscillator loop is further reflected by the PBS and thereby made to enter a photodiode (PD3), which detects RF amplitude modulation of the light. Another RF signal is obtained from the RF output port of the short oscillator loop, then processed through a variable attenuator (VA) and variable phase shifter (VP1), then made to interfere with the RF output of PD3. The VA and VP1 are adjusted so that output port 1 of the bridge passes minimum power while output port 2 of the bridge passes maximum power.

The signals from the two ports are amplified, and the amplified signal at port 1 is further processed by another variable phase shifter (VP2) to set the phase difference between the two signals at either 0 or π radians. The signals are then mixed with each other in a balanced mixer. As explained in more detail below, the mixer output is processed into an error signal that is fed back to VCP to control the frequency of oscillation.

The long optical fiber in the long oscillator loop acts as both a high-Q (where Q is the resonance quality factor) storage component for the oscillator and as a frequency-discriminator component for the carrier-suppression bridge. The bridge acts as a frequency discriminator in that it converts the frequency jitter of the OEO into amplitude jitter in the output of the bridge. The role of the mixer is to detect this amplitude jitter. The output of the mixer is amplified, filtered, and fed back to VCP to reduce the frequency jitter (and thus the phase noise) of the OEO.

This work was done by Steve Yao, John Dick, and Lute Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20546, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Dynamic Holographic Optical-Interconnection System

Dynamic HOE switches can be constructed more simply than was previously possible.

Lyndon B. Johnson Space Center, Houston, Texas

An improved visual display system for a helmet produces two- and three-dimensional images by use of the limited domain of spatial light modulation (SLM) values. One especially notable improvement incorporated into the design of this system is a simplification in the design of dynamic holographic optical element (HOE) switches. This system can be expected to afford immediate and calculable benefits to the United States space program; similar benefits for the military and private industry are also anticipated.

This system generates small volumes of three-dimensional images, satisfies the size constraints of space-related applications, and offers significant improvements over pre-existing holographic helmet displays. Visual display systems that render two- and three-dimensional images for space applications offer a major advantage over pre-existing systems: it is possible to develop distinct and specifiable phase relationships between the elements of either two- or three-dimensional arrays. As an extension of the work that produced the present system, a more efficient means of storing holographic images was created. This system is a major improvement over prior means for storing holographic images, in that it significantly refines holographic helmet displays and the information that can be generated from them.

Holographic images are used most often in helmet visual displays. In the design of the present system, the required optical interconnections are made when SLMs direct coherent light beams into the light patterns needed for applications. In this way, optical reciprocity, which enables a single receiver to obtain light from a reprogrammable array of source locations, is achieved. Optical reciprocity takes advantage of the complex nature of SLMs and enables the use of continuously variable modulators with coupled phase and amplitude characteristics. One application involves focusing of light from a single source placed at arbitrary locations in a three-dimensional array, enabling spatial addressing of nonlinear optical storage media; a second application involves the creation of two-dimensional arrays of spots for optical interconnections.

In broadband communications, signals with very large bandwidths are often transported on light carriers. The connections between sources and destinations must be reconfigurable so that light can be distributed to the intended destinations. Although a great deal of work has already been done on switching light signals, the utility of SLMs as switches has been limited by conflicts among requirements and capabilities that pertain to speed and complex values: A fast SLM is often restricted to a binary set rather than a continuum; a continuously variable SLM is restricted to, at most, the curvilinear subset of a complex unit disk. In the design of the present system, the limited domain of SLM values is maximized, creating a dynamic HOE switch with a design simpler than that of any such switch constructed previously.

To simplify the switch design, the researcher who developed the present system first had to simplify some computation-intensive annealing techniques. He devised an innovative method of optimizing a metric, the value of which is related monotonically to a measure of the quality with which an HOE performs an optical switch function. By doing this, he discovered that HOEs can be computed for the curvilinear continuum of complex values

typical of readily available SLMs, but this was only a single improvement. He also examined conventional HOE computation techniques to discover ways of improving these as well.

Since conventional HOE computation techniques are often iterative, problems can arise. To ameliorate any problems, the researcher developed a means of directing light from a single source to many receivers. This made it possible to specify and optimally realize the intensity and phase of light sent to receivers. The receivers can be detectors that convert light into other forms (electrical signals or photographs), locations in a photo-addressed nonlinear optical information storage device, or ducts that can transmit more light.

The optical setup devised for the receivers is simple: An SLM is disposed in a beam of light, where its complex characteristics are used to change an arriving light wave into an approximation of an ideal departing light wave. The single departing light wave is separated into three light waves that converge on different locations that need not be coplanar. The incoming beam of light is directed to a pattern of three spots. A collimating lens is not necessary but can be used if convenient.

After simplifying the setup, the researcher next determined the optimum set of values of transmittance. For a given value of k, the ideal values of the light-wave phasor were optically represented on a curvilinear SLM domain by the Euclidean closest values. (For this purpose, the SLM domain was represented as a curvilinear continuum; it was not restricted to a binary set.) Next for a given value of k, the ideal values of the light-wave phasor were represented on a discrete SLM domain by the Euclidean closest values. Although the SLM is ternary (three-valued) domain, the ideal values are the same as the nonrestricted binary values.

This work was done by Richard D. Juday of **Johnson Space Center**. *Further information is contained in a TSP [see page 1].*

This invention has been patented by NASA (U.S. Patent No. 5,768,242). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22746.

Signal Processor for Doppler Measurements in Icing Research

Short, high-frequency bursts on noisy backgrounds can be processed in real time.

John H. Glenn Research Center, Cleveland, Ohio

An advanced signal processor has been developed to enable high-resolution measurement of the frequency and phase shifts of noisy laser Doppler velocimeter (LDV) and phase Doppler particle analyzer (PDPA) signals. The purpose of the measurements is to exploit the phase Doppler principle to determine the sizes and velocities of droplets entrained in airflows. By enabling such measurements, this signal processor is making it possible to perform ground-breaking research in icing of airplanes and combustion of liquid fuels, involving (1) water-droplet-laden, high-speed airflows that simulate clouds flowing past airplanes and (2) high-speed, dense sprays of liquid fuels, respectively.

The phase Doppler signals of interest are bursts with transit times <1 μs, components at frequencies that range up to and somewhat beyond 100 MHz, and moderate-to-poor signal-to-noise ratios. Heretofore, there has been an option to postprocess the signals in a computer; of course, this option precludes real-time processing. There has been an option to use analog signal-processing circuitry, but this option has necessitated higher signal-to-noise ratios. There has also been an option to use digital signal-processing circuitry, but this option has offered limited ability to process high-frequency signals.

The present signal processor operates in real time. It includes two analog-to-digital converters that operate at a sampling frequency of 160 MHz and at a phase shift of 90° relative to each other, so that they offer an effective sampling frequency of 320 MHz. Signals at frequencies up to 150 MHz can be measured. Processing involves the use of Fourier-transform techniques to detect bursts and to retrieve signals from a noisy background (signal-to-noise ratio as low as −5 dB). Furthermore, accurate measurements can be taken in limited numbers of samples, making it possible to extract useful information in transit times as small as 0.25 μs.

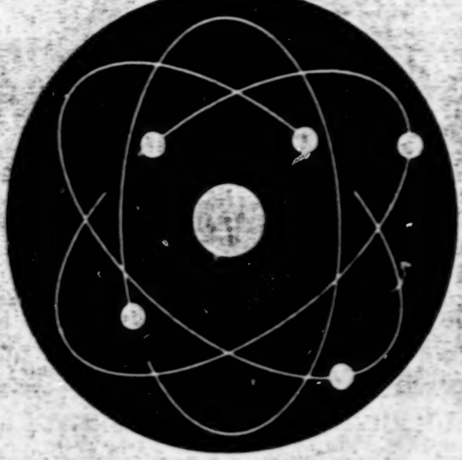
This work was done by Larry Berkner of TSI Inc. and Khalid M. Ibrahim and William D. Bachalo formerly of TSI Inc. for **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16993.

System for Monitoring the Environment of a Spacecraft Launch

A system that includes sensors and computers that communicate via an intranet enables both real-time monitoring and subsequent analysis of acoustic, overpressure, and thermal aspects of a spacecraft-launch environment and the structural response (vibration and strain) to that environment. The sensors include microphones, accelerometers, strain gauges, and a thermocouple attached to a cantilever beam mounted vertically on the roof of a building near a launch pad. The sensors are connected via cables to signal conditioners inside the building. The conditioned sensor outputs are coupled to a digital audio tape (DAT) recorder that is monitored and controlled by a computer denoted the "remote" computer. A host computer in a different building communicates with the remote computer via the intranet, using the Transmission Control Protocol/Internet Protocol. Ambient test conditions can be monitored in real time before a launch. Last-minute adjustments can be accomplished remotely and dynamically. A few minutes before the launch, the DAT recorder is turned on to record launch events. Data can be monitored in real time during the launch. After the launch, data can be copied from the DAT recorder onto the remote computer and then transferred to the host computer for plotting and analysis.

This work was done by Raoul E. Caimi of **Kennedy Space Center** *and Ravi N. Margasahayam of Dynacs Engineering Co., Inc.*
KSC-12060



Physical Sciences

Hardware, Techniques, and Processes

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Small Low-Temperature Thermometer With Nanokelvin Resolution

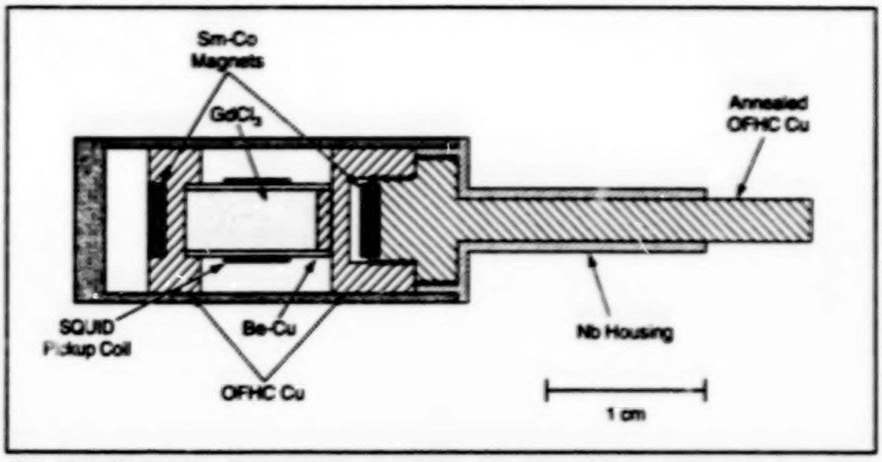
The magnetic field is generated by permanent magnets instead of a solenoid.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved high-resolution thermometer (HRT) for use in scientific experiments at temperatures <4 K has been developed. Like other, previously developed low-temperature HRTs, this device is based on the strong temperature dependence of the magnetization of a paramagnetic salt exposed to a magnetic field. However, in comparison with other paramagnetic-salt HRTs, this one is smaller and less massive; hence, it is denoted "sHRT" — short for "small HRT."

The temperature-sensitive part of an HRT of this type is a pill-like piece of the paramagnetic salt $GdCl_3$. The magnetization of the salt pill is measured by use of a superconducting quantum interference device (SQUID). In an older device of this type, the magnetic field needed to magnetize the pill is trapped in a long superconducting tube (flux tube) that must be charged by use of a superconducting solenoid; typically, the overall length and mass of such an HRT are ≈0.3 m and ≈10 kg, respectively. In contrast, the length and mass of the sHRT are ≈3 cm and ≈7 g, respectively.

The reductions in size and mass are made possible by using permanent magnets instead of a charging solenoid and flux tube to impose the magnetic field. In the sHRT (see figure), two small samarium cobalt permanent magnets are placed near opposite ends of a beryllium copper cylinder filled with $GdCl_3$. To enhance the thermal link between the $GdCl_3$ and the immediate surroundings, the ends of the Be-Cu cylinder are capped with oxygen-free high-conductivity (OFHC) copper blocks, into which numerous chimney-shaped fins have been machined. A SQUID pickup coil made of Nb-Ti wire is wound on the Be-Cu cylinder. The sHRT housing is made of Nb, which is a superconductor and thus effective in shielding the pickup coil against any ambient magnetic field.



This **High-Resolution Thermometer** is smaller and less massive, relative to prior thermometers based on paramagnetic salts.

In tests, the sHRT was found to yield measurements with a temperature resolution of $\approx 10^{-9}$ K at a temperature near the liquid-gas critical point of ^3He ($\approx$3.31 K). The drift rate of the sHRT was found to be $<2 \times 10^{-13}$ K/s.

This work was done by Inseob Hahn of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
NPO-20903

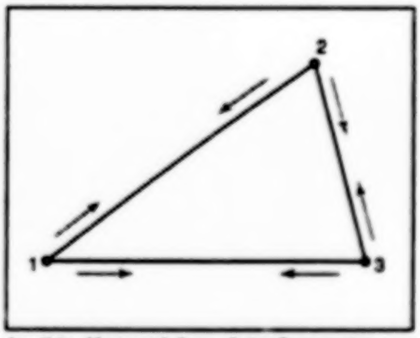
Time-Delay Interferometry in an Unequal-Arm Interferometer

Neither equal arm lengths nor precise oscillators are necessary.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of processing phase measurements in a large, unequal-arm laser Michelson interferometer makes it possible to measure phase effects much smaller than the laser phase noise. This method is related to the method reported in "Cancellation of Laser Noise in an Unequal-Arm Interferometer" (NPO-20611) *NASA Tech Briefs*, Vol 24, No. 3 (March 2000), page 22a.

In the original application for which the method has been proposed, the interferometer, used to detect gravitational waves, would be based on three spacecraft flying in a triangular formation with arm lengths of the order of 5×10^6 km. In principle, the method could also be utilized in other applications in which one seeks to measure relative lengths, relative velocities, phases, or frequencies interferometrically with high precision. The method is fundamentally different from conventional interferometric methods in which one relies on equal arm lengths to cancel laser phase noise. The method is also fundamentally different from conventional two-way Doppler interferometry, in which one relies on a precise oscillator to maintain coherence.



In this **Unequal-Arm Interferometer**, a laser at each corner is used to transmit light to, and as a local oscillator in receiving light from, the other two corners.

In an interferometer of the type to which the method applies, a free-running laser at each corner of the triangular formation transmits a beam to each of the other two corners (see figure). Thus, the interferometer can also be characterized as a closed triangular array of six one-arm delay lines between the corners. The transmitting laser at each corner also serves as a local oscillator for reception of the beams transmitted by the lasers at the other two corners. The raw data output of the receiver at each corner consists of two Doppler time series — one for each of the two interferometer arms that intersect at that corner. Each of the total of six Doppler time series embodies phase and frequency contribu-

tions that include laser phase noise, phase noise from secondary sources, and the phase effect of interest. Typically, the phase effect of interest is a Doppler effect caused by changing arm length and/or a gravitational wave that crosses the interferometer. The laser phase noise is the largest source of noise in these measurements.

In this method, the Doppler time series are recorded and postprocessed to cancel all laser phase noise and extract the phase effect of interest. The line of reasoning that leads to the postprocessing algorithm begins with recognition of the following fact concerning each of the delay lines: The Doppler time series generated at the receiving corner at a given time, t, contains the difference between (1) the phase or frequency noise of the laser at the receiving corner at time t and (2) the phase or frequency noise of the laser at the transmitting corner at time $t - L/c$, where L is the length of the delay line and c is the speed of light.

By a lengthy but straightforward mathematical derivation, it can be shown that by (1) delaying each Doppler time series by a suitable interval equal to the delay in the same delay line, a different delay line, or some combination of delay lines and (2) forming suitable linear combinations of the variously delayed Doppler time series, one can obtain complete cancellation of the effects of the phase noises in all three lasers. The phase effect of interest (e.g., of a gravitational wave) is not canceled; instead, it appears in the linear combination as a multipulse response that depends on the specific linear combination and the interferometer geometry.

This work was done by John Armstrong, Frank Estabrook, and Massimo Tinto of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-20739

Optical Measurement of Temperatures in Muscles and Tendons

Small, electrically and chemically neutral sensors would be implanted surgically.

NASA's Jet Propulsion Laboratory, Pasadena, California

Miniature fiber-optic-coupled sensors based on optically excited, self-resonant microbeams have been proposed for measuring temperatures within muscle fascicles and tendons. The proposed sensors could be used in medical and biological research on humans and other animals. The proposed sensors would be variants of those described in two articles in *NASA Tech Briefs*: "Proximity Measurement of Pressure and Temperature" (NPO-20223), Vol. 22, No. 1 (January 1998), page 48; and "Measurement of Stresses and Strains in Muscles and Tendons" (NPO-20464), this issue, page 55.

Each sensor would be made of electrically nonconductive materials that are chemically and galvanically inert with respect to living tissue. Typical sensor dimensions would be about 0.5 by 0.5 by 0.1 mm. These dimensions are suitable for surgical implantation in muscle and tendon tissues; these dimensions are also comparable to diameters of cores of multimode optical fibers, making the sensors amenable to fiber-optic coupling.

Each sensor would contain a cantilever microbeam located in a vacuum cavity in a housing. The beam would serve as an optomechanical resonator (as explained below) with a resonance frequency of the order of a megahertz and a resonance quality factor (Q) of the order of 10^5. The beam would face an integral, embedded photodiode that would be coupled to external instrumentation via a multimode optical fiber. Taken together, the beam and vacuum cavity would constitute a quarter-wave Fabry-Perot interferometric structure.

Optical excitation supplied via the optical fiber would cause the photodiode to generate a voltage that would bend the beam via electrostatic attraction. Following initial bending, the beam would vibrate at its natural resonance frequency. Because the beam and vacuum cavity would constitute a quarter-wave Fabry-Perot interferometric structure, the vibrations would give rise to modulation of the incident light reflected from the beam. The modulation of the light would alter the photovoltage and thereby contribute to a feedback mechanism that would sustain the resonant vibration. In addition, the modulated light reflected into the fiber would travel to the far end of the fiber, where a photodetector would convert the modulation to a quasi-digital stream of electrical pulses. The pulse stream would be fed to a counting circuit to determine the frequency of vibration.

The beam would be made of polycrystalline silicon doped to have a high thermal coefficient of stiffness, so that its resonance frequency would vary appreciably with temperature. Typically, the temperature coefficient would be such that measurements of frequency could be converted to temperature measurements with resolutions as small as a millidegree. The dynamic range of the sensor would be of the order of 10^6.

This work was done by Frank Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-20562

Nanometer-Level Control Scheme for Nulling Interferometry

Path lengths in an interferometric beam combiner are offset to maximize an off-null error signal.

NASA's Jet Propulsion Laboratory, Pasadena, California

A control scheme for nulling interferometry has been devised to make it possible to stabilize interferometric optical-path-length differences to within approximately a nanometer. This degree of stabilization is an order of magnitude finer than that achieved previously in typical optical interferometers.

Nulling interferometry is a promising technique for reducing the apparent brightness of a star relative to its surroundings. As such, nulling interferometry has potential to enable direct detection of extrasolar planets and zodiacal light. Nulling interferometry is based on the precise cancellation, or "nulling," of the starlight received from the same star by two side-by-side telescopes. To cancel on-axis starlight, the electric fields from the two telescopes must be combined in opposite phase at all wavelengths across the waveband of interest. The required degree of cancellation (to the 10^{-6} level in the infrared) translates to a requirement to stabilize optical-path-length differences at or below the nanometer level.

In the present technique, the required achromatic π-radian phase shift between the beams from the two telescopes is introduced by geometrically flipping the

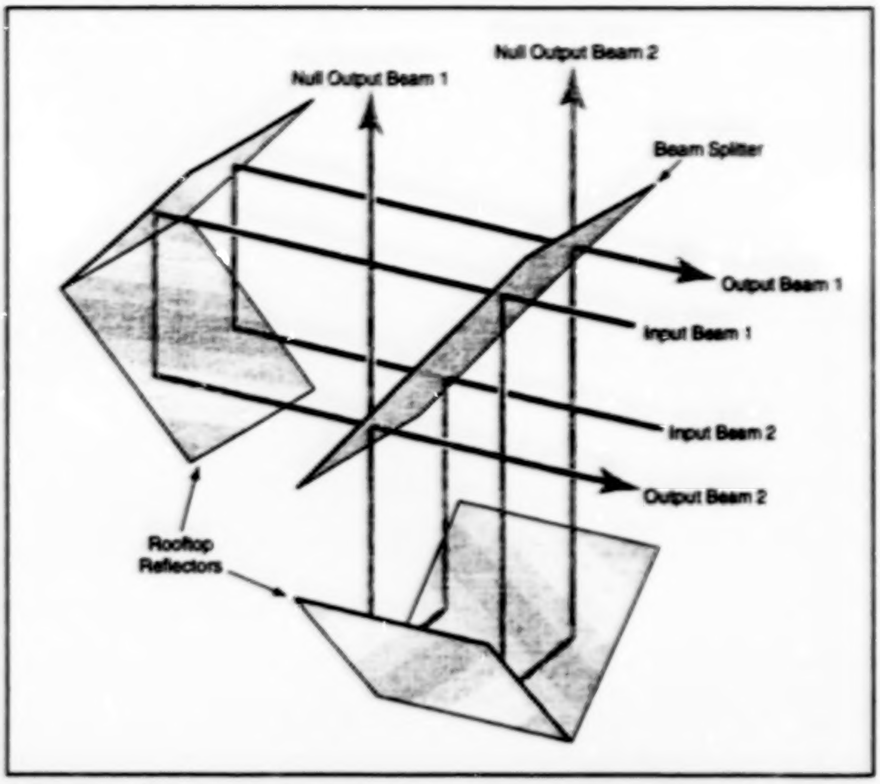
electric-field vector of one beam, relative to the other, by use of a rotational shearing interferometer (RSI). The figure schematically depicts aspects of an RSI. The two interferometer arms contain orthogonal rooftop reflectors, and the arms intersect at a beam splitter. Each rooftop flips one of two orthogonal components of the electric-field vector. This RSI generates two null output beams that are balanced in the sense that the intensity of the light in both of them is proportional to rt, where r and t are the reflection and transmission coefficients, respectively, of the beam splitter. This RSI also generates two bright outputs that are unbalanced in the sense that they are proportional to r^2 and t^2, respectively.

In order to generate a sufficiently strong feedback signal for controlling the optical-path-length difference between the two arms to maintain the null, one must find a source other than the nominally nulled star itself. The present control scheme exploits a hitherto unrecognized property of interferometric beam combiners in general and of this RSI in particular to generate a sufficiently strong control signal. The scheme involves the insertion of a path offset of $\lambda_m/8$ (where λ_m is approximately the mean wavelength in the wavelength band of interest) into one of the interferometer arms and the insertion of another path offset of $\lambda_m/8$ into the path (outside the interferometer) of one of the input beams.

Because the path-length offsets add in one nulled output and subtract in the other, these offsets make it possible to preserve the achromatic null in one of the two nominally balanced output beams while converting the other beam into a bright off-null error signal, in which the fractional change in power level is given by

$$2\pi\frac{\Delta x}{\lambda_m},$$

where Δx is the path-length difference that one seeks to minimize. For example, at a wavelength of 628 nm, this scheme yields an error signal with a fractional power change of 1 percent per nanometer of path-length difference; even at a path-length difference of only 1 nm, this fractional power is much greater than the fractional power remaining in the nominally nulled output signal. Although the error-signal beam is chromatic, this is not of concern because achromaticity is needed only in the null output beam.



A Rotational Shearing Interferometer with two orthogonal rooftop reflectors is used as an interferometric beam combiner. With a proper choice of internal and external optical-path-length offsets, it is possible to convert one of the null output beams into a relatively bright off-null indicator for use as feedback in maintaining the null of the other null output beam.

This work was done by Gene Serabyn of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-20758

Apparatus Would Extract Water From the Martian Atmosphere

A report proposes an apparatus that would extract water from the atmosphere of Mars and would consume little energy in doing so. The apparatus would include a set of copper plates surrounded by a thermal shield with slots through which atmospheric gas could circulate. At night, the slots would be open and the plates would be cooled to a temperature ≤170 K by thermally coupling them to a radiator facing the sky. Assuming that in the nighttime Martian atmosphere at ground level, the temperature is ≈200 K and the concentration of water vapor is at or near saturation, the vapor would condense and freeze on the plates. During the day, the slots would be closed and plates would be heated by thermally coupling them to a small solar collector; this would cause the ice to melt, and the water thus produced would be collected.

This work was done by Pramod K. Sharma of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Passively Operated Unit for Extraction of Water from the Mars Atmosphere," see TSP's [page 1].*
NPO-20843

Review of Research on Supercritical vs. Subcritical Fluids

A paper reviews theoretical and experimental research on the behaviors of supercritical fluids and, for comparison, subcritical fluids. Experiments with drops, isolated or in groups, streams, shear layers, mixing layers, jets, and sprays are tabulated and discussed as a precursor to forming a concept of fluid behavior. The physics of the supercritical and subcritical regimes is discussed, and major differences between observations in the two regimes are identified and explained. Various mathematical models of supercritical fluids are examined in the context of drop studies, and salient aspects of fluid behavior are identified. Special attention is paid to an experimentally validated model in which differences between subcritical

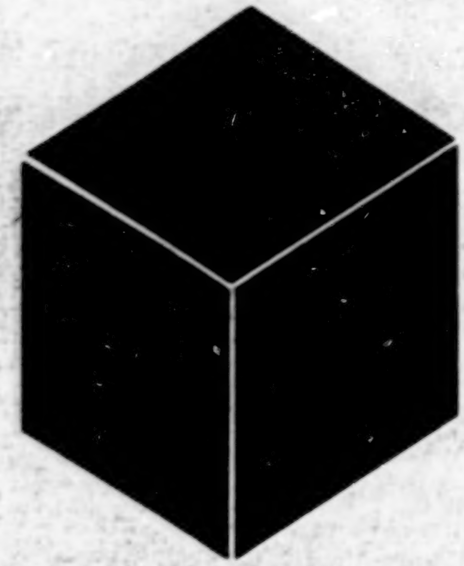
and supercritical behavior are interpreted in terms of lengths scales: Because of these differences, the traditional Lewis-number expression does not accurately portray the ratio between the heat-transfer and mass-transfer length scales in supercritical fluids. Therefore, an effective-Lewis-number expression that gives a realistic estimate of the ratios is recommended. There is a discussion of the use of various models, including the validated one, to describe supercritical fluids under conditions relevant to liquid-fuel rocket, diesel, and gas turbine engines. Finally, promising areas of current and future research are described.

This work was done by Josette Bellan of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the paper, "Supercritical (and Subcritical) Fluid Behavior and Modeling: Drops, Streams, Shear and Mixing Layers, Jets and Sprays," see TSP's [page 1].*
NPO-20893

Study of Fusion-Driven Plasma Thruster With Magnetic Nozzle

A report presents a computational study of a proposed plasma thruster for a spacecraft. In the study, it was assumed that (1) a direct-conversion nuclear-fusion source capable of providing a high-energy electron beam would be available, (2) the electron beam would heat a plasma formed from a working fluid (hydrogen), (3) the plasma would expand through a nozzle to produce thrust, and (4) an applied poloidal magnetic field would insulate the material nozzle from the plasma and would be essential to the transfer of energy from the electron beam to the plasma. The behavior of the plasma was computationally simulated by use of a mathematical model of magnetohydrodynamic flow implemented in the previously developed MACH2 computer program. To increase the accuracy of modeling of the magnetic field, MACH2 was modified by providing for an arbitrary number of current loops used to generate the applied magnetic field and by splitting the total magnetic field into applied and plasma-induced components. The results of the computational simulations contribute to understanding of the appropriate parameter regimes for the electron beam, the inflowing working fluid, and the applied magnetic field. In addition, the modified version of MACH2 could be used to design magnetically nozzled thrusters of all types.

This work was done by Michael H. Frese, John J. Watrous, and Richard A. Gerwin of NumerEx for **Marshall Space Flight Center**. *To obtain a copy of the report, "A Fusion-Driven Earth to Orbit Thruster," see TSP's [page 1].*
MFS-31390



Materials

Hardware, Techniques, and Processes

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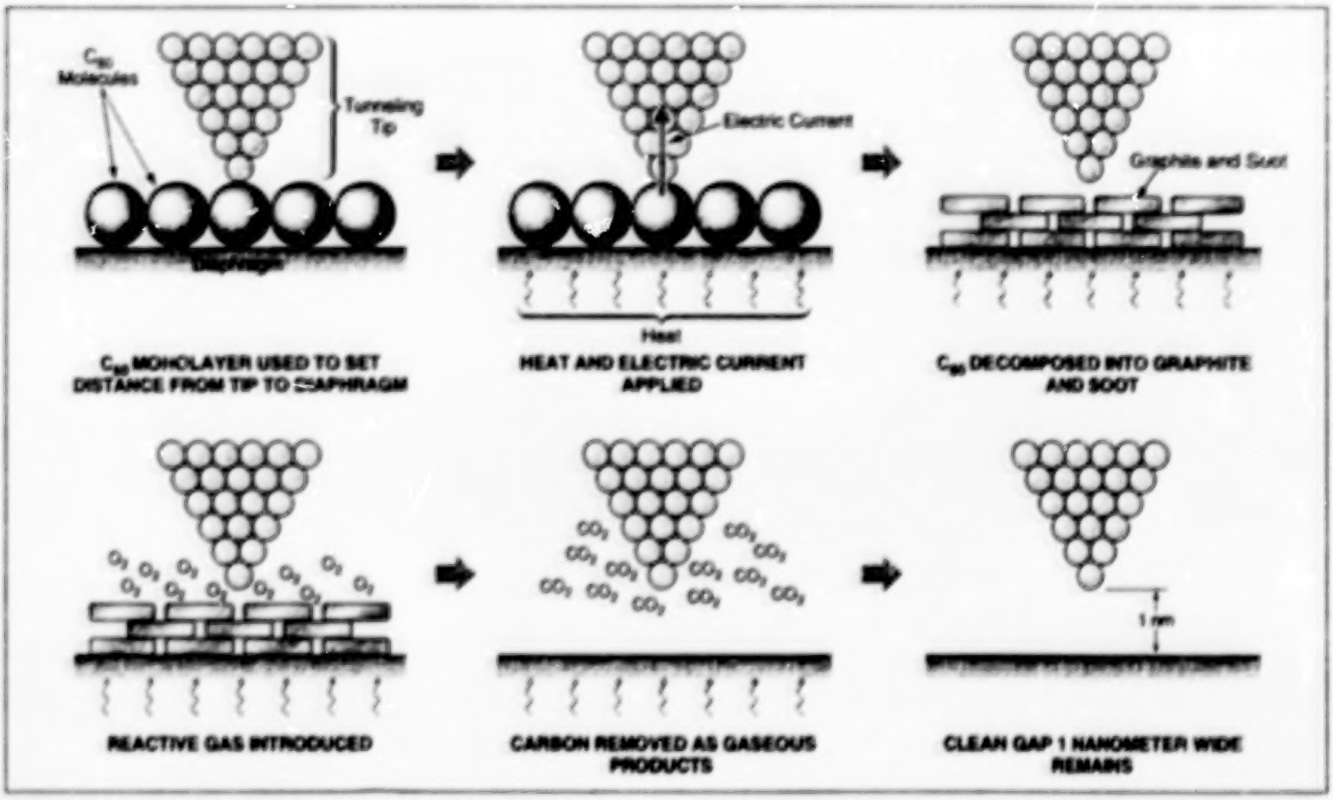
Temporary Fullerene Films in Microelectromechanical Devices

These films would be used to protect and position quantum-mechanical-tunneling tips.

NASA's Jet Propulsion Laboratory, Pasadena, California



A Monomolecular Layer of C_{60} would be deposited on the diaphragm, then used to set the distance between the tunneling tip and the diaphragm, then removed thermochemically.

In a proposed technique for fabrication of microelectromechanical devices, thin films of fullerenes would be used as temporary packaging to protect and position delicate components. The initial application of this technique would likely occur in the fabrication of devices in which quantum-mechanical tunneling of electrons across gaps about 1 nm wide would be exploited to measure subnanometer displacements of the components facing each other across the gaps.

Typically, a tunneling device of this type includes a pyramidal metal tip that faces a gold-coated diaphragm across the tunneling gap. In present fabrication practice, the initial gap is set by moving the tip and diaphragm toward each other under manual control until a tunneling current is measured. Often, the tip and diaphragm are accidentally brought into contact, with consequent damage to either or both.

The proposed technique calls for deposition of a monomolecular layer of the fullerene C_{60} on the diaphragm prior to setting the gap (see figure). The C_{60} molecular unit is approximately spherical and, fortuitously, is 1 nm wide. Thus, the monomolecular layer of C_{60} would not only prevent contact between the tip and diaphragm but would also automatically establish the desired gap thickness. It would still be necessary to position the tip and diaphragm as in current fabrication practice, but tunneling current would no longer be used as the position indicator; instead, exploiting the electrical conductivity of C_{60}, one would simply monitor for contact between the tip and the C_{60} film, as indicated by the onset of electrical conductance between them.

Once the fullerene film had served its purpose, it would be removed (either during fabrication or at any suitable time thereafter). If the film were weakly chemisorbed on the diaphragm, it might be removable by simple heating. Otherwise, a more-complex removal process would include the application of both externally generated heat and an electrical current through the tip/C_{60}-film contact; the combination of externally supplied heat flux and current would have to be large enough to heat the C_{60} film in the vicinity of the tip sufficiently to break down the C_{60} into graphite and soot, but not so large as to damage the tip or the diaphragm. The resulting hot carbonaceous contaminants would be removed by chemical reaction with O_2 (or perhaps with Cl_2 and/or H_2) to form CO_2 and/or other gaseous species.

The O_2 or other reactive gas could be supplied via a channel with a one-event valve; such channels and valves are commonly included in microelectromechanical devices and systems. The CO_2 and/or other gaseous product(s) could be adsorbed onto a sacrificial (getter) surface that had been fabricated previously as an integral part of the device. As a result, the region around the tip would be free of fullerene, carbonaceous contaminants, or adsorbed gas.

This work was done by John D. Olivas of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL [see page 1]. Refer to NPO-20148.

Modular Cryogenic Insulation

Principal advantages are long life and low density.

John F. Kennedy Space Center, Florida

"Modular cryogenic insulation" denotes a chaff for installation in the partially evacuated annular spaces between the inner and outer walls of tanks used to store and transport liquid nitrogen and other cryogenic liquids. The insulating chaff was developed to replace low-density powders (e.g., perlite, silica aerogel, carbon black, or diatomaceous earth) that have been used to insulate cryogenic tanks. Thermal cycling of a tank causes some of the powder to fall to the bottom of the annular space; over time, the powder accumulates in the bottom and becomes compacted there, with consequent loss of thermal-insulation performance. In addition, the compaction generates stresses that can damage the tank. The chaff was selected from among several candidate materials that were investigated to find one that would not settle with thermal cycling, would be readily manufacturable, would offer the requisite thermal-insulation performance, would thermally expand and contract along with the tank walls, and could be installed easily.

The starting material for the manufacture of the chaff is Mylar (or equivalent polyethylene terephthalate) coated on both sides with thin film of aluminum. The material comes in rolls and is conventionally used to form multilayer insulation (MLI) blankets for some cryogenic applications. The rolled Mylar is unwound and processed through a cross-cut shredder to produce the chaff. Like an insulating powder, the chaff is poured into the annular space of a tank through a hole on the top of the outer tank wall.

The thermal performance of the chaff approximates that of perlite powder within 10 percent. Although the initial cost of the chaff is higher than that of perlite powder, the life-cycle cost of the chaff is lower, because settling of the powder makes it necessary to replace the powder during the life of a typical cryogenic tank, whereas there is no need to replace the chaff because it does not settle. Moreover, because the chaff does not settle, a tank insulated with the chaff does not exhibit the increased heat leakage observed in a powder-insulated tank after a few years of the useful life of the powder. Yet another advantage of the chaff is low density — less than 10 percent of the density of a typical insulating powder.

This work was done by Richard L. Jetley of Aerospace Design & Development, Inc., for **Kennedy Space Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-11912.

High-Performance POSS-Modified Polymeric Composites

Mass densities will be decreased, while strength, use-temperature range, and radiation resistance will be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

Epoxies and/or cyanate esters that incorporate polyhedral oligomeric silsesquioxane (POSS) compounds are undergoing development at Air Force Research Laboratory (AFRL). These formulations are expected to be useful as high-performance matrix resins for advanced, lightweight fiber/matrix composite materials for diverse applications that could include spacecraft structures, automotive structures, prosthetics, sporting goods, and general consumer goods. In comparison with the corresponding unmodified matrix resins and composite materials made with those resins, the POSS-modified resins and composite materials are expected to exhibit lower mass densities, greater stiffness, and capabilities to withstand higher temperatures and higher levels of ionizing radiation.

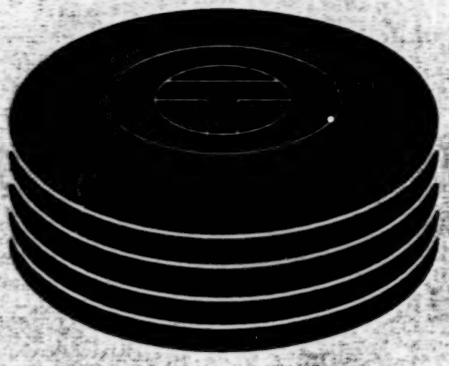
Preliminary experiments have confirmed expectations that in comparison with unmodified resins, POSS-modified epoxy resins exhibit enhanced properties — especially lower mass density and widened use-temperature ranges. Both analyses and favorable initial results suggest that POSS-modified matrix resins are both chemically compatible with, and capable of wetting, binding fibers to desirably high degrees.

Specific quantitative goals in the development of POSS-modified polymeric composites, relative to unmodified ones, include the following:

- Parameters that represent such matrix-dominated mechanical properties as compression strength, durability under heat/load cycling, and resistance to impact and damage, will be increased by 10 to 50 percent.
- Mass densities will be reduced by at least 15 percent.
- Use-temperature ranges will be extended by >80 °C.
- Resistance to atomic oxygen and to ultraviolet and charged-particle radiation will be increased by 100 percent.
- Flammability will be decreased and other physical properties will be enhanced.

(This concept has not been reduced to practice.)

This work was done by Witold Sokolowski and Tim O'Donnell of Caltech, Joseph Lichtenhan of Hybrid Plastics Co., and Shawn Phillips of AFRL Edwards for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP [see page 1].*
NPO-20734



Computer Programs

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Mathematics and Information Sciences

Program Automates Management of IBM VM Computer Systems

The VM Automated System computer program was developed to satisfy a need for efficient management of operations in a large client/server computer network that includes multiple mainframe computers and multiple local-area subnetworks. Functions performed by the program include the following:

- Automated and operator-assisted scheduling,
- Graphical user interfaces for scheduling and monitoring,
- Automated diagnosis of the integrity and operational status of the system,
- Management of client/server application programs that depend on data and/or software that reside on other computers, and
- System-management functions (including shutting down or starting up a subsystem and/or system, with automation making it unnecessary for the system operator to memorize the proper sequence of commands).

This work was done by Stephen Scott Tribbey, Debra S. Sheets, Scott C. McIlroy, and Kirk P. Matthews of **Kennedy Space Center**.
KSC-11901

Mechanics

Hardware, Techniques, and Processes

Computer Program Predicts Rocket Noise

Parameters and configurations can be varied as needed.

John F. Kennedy Space Center, Florida

A computer program predicts the noise and ignition over pressure in the vicinity of a rocket during launch. The program has been developed to complement the vibroacoustic-prediction effort for rockets now in use and to provide the capability for prediction of vibroacoustic loads associated with next-generation rockets. Programs like this one are vital parts of the implementation of NASA's "better, faster, cheaper" philosophy; they are needed because full-scale acoustic and vibration testing of launch vehicles or payloads is often difficult, time-consuming, and prohibitively expensive.

This program implements an empirical model based partly on recognition that noise in each frequency band of interest is generated throughout the rocket-engine flow. The empirical model utilizes accumulated data from noise and structural-vibration measurements performed on the space-shuttle launch pad since 1984.

The program is user-friendly. It provides for interactive modification of various parameters that affect the noise environment. Predictions can be made for any position on a launch vehicle and for both near- and far-field positions on the ground. Predictions can be made for both flight-readiness firing and liftoff, for a variety of vehicle and launch-mount configurations (including single or multiple engines and open or closed duct), and for any altitude of the vehicle during ascent.

The program can be represented, in simplified form, by the following set of instructions:

1. Determine the flow axis relative to the vehicle and stand.
2. Estimate the overall acoustic power (in watts) from engine thrust, number of nozzles, fully expanded exit velocity, and acoustic-efficiency values.
3. Convert the overall acoustic power level from watts to decibels.
4. In the case of a rocket with multiple nozzles, calculate the effective nozzle-exit diameter.
5. Compute the core length of the plume or the normalized plume core length (normalized to the effective nozzle-exit diameter).
6. Estimate the number of identical slices of the plume for analysis.
7. Determine the normalized acoustic power per unit of the plume core length for each identical slice along the plume.
8. Calculate the overall acoustic power for each of the plume slices.
9. Convert the normalized spectrum for rockets to a conventional acoustic bandwidth (i.e., the power spectrum per hertz or per 1/3 octave band, as desired) for each slice of the plume.
10. Compute the sound-pressure level at any given position on the vehicle for each plume slice and for each 1/3-octave band, inclusive of the effects of directivity.
11. Calculate the sound-pressure level at any given position on the vehicle for all plume slices by logarithmic summation of contributions from each slice.
12. Finally, compute the overall sound-pressure level (OASPL) by logarithmic summation for all plume slices and all 1/3 octave bands.

The program includes the input parameters and the computed outputs. Among the computed outputs are the 1/3-octave band number, the center frequency of each band, the width of the frequency band, and the sound-pressure level in that band. A plot of sound-pressure level for each 1/3-octave band number is also generated for use in developing specifications for qualification tests.

This work was done Raoul E. Caimi of **Kennedy Space Center** *and Ravi N. Margasahayam of Dynacs, Inc. Further information is contained in a TSP [see page 1].*
KSC-12061

Passive Venting for Alleviating Helicopter Tail-Boom Loads

Preliminary results indicate that venting could be used to advantage.

Dryden Flight Research Center, Edwards, California

The tail boom of a single-rotor helicopter is subjected to a complex flow field that includes the wakes of the main and tail rotors, the freestream, and the wake from the forward fuselage. Hovering and sideward flight present the operational regimes that are most critical with respect to adverse sideward and downward loads on the tail boom. These adverse loads necessitate additional engine power, thereby reducing payload, performance, and available yaw-control margins. In addition, nonlinear side-force gradients near conditions of boom stall can make precise yaw control very difficult for the pilot. The addition of strakes to the tail boom is one method that has been used to modify the flow field and reduce these adverse loads.

Figure 1. The UH-60 Helicopter was used as the baseline helicopter in a study of the effect of venting the tail boom.

In recent research on fixed-wing aircraft, porosity of surfaces has been used to alter distributions of pressure (and thus loads) on the surfaces. It was postulated that, by passively venting portions of a helicopter tail boom (generally represented as a blunt body), the pressure distribution and therefore the loads on the boom could be modified in a favorable manner. Various venting

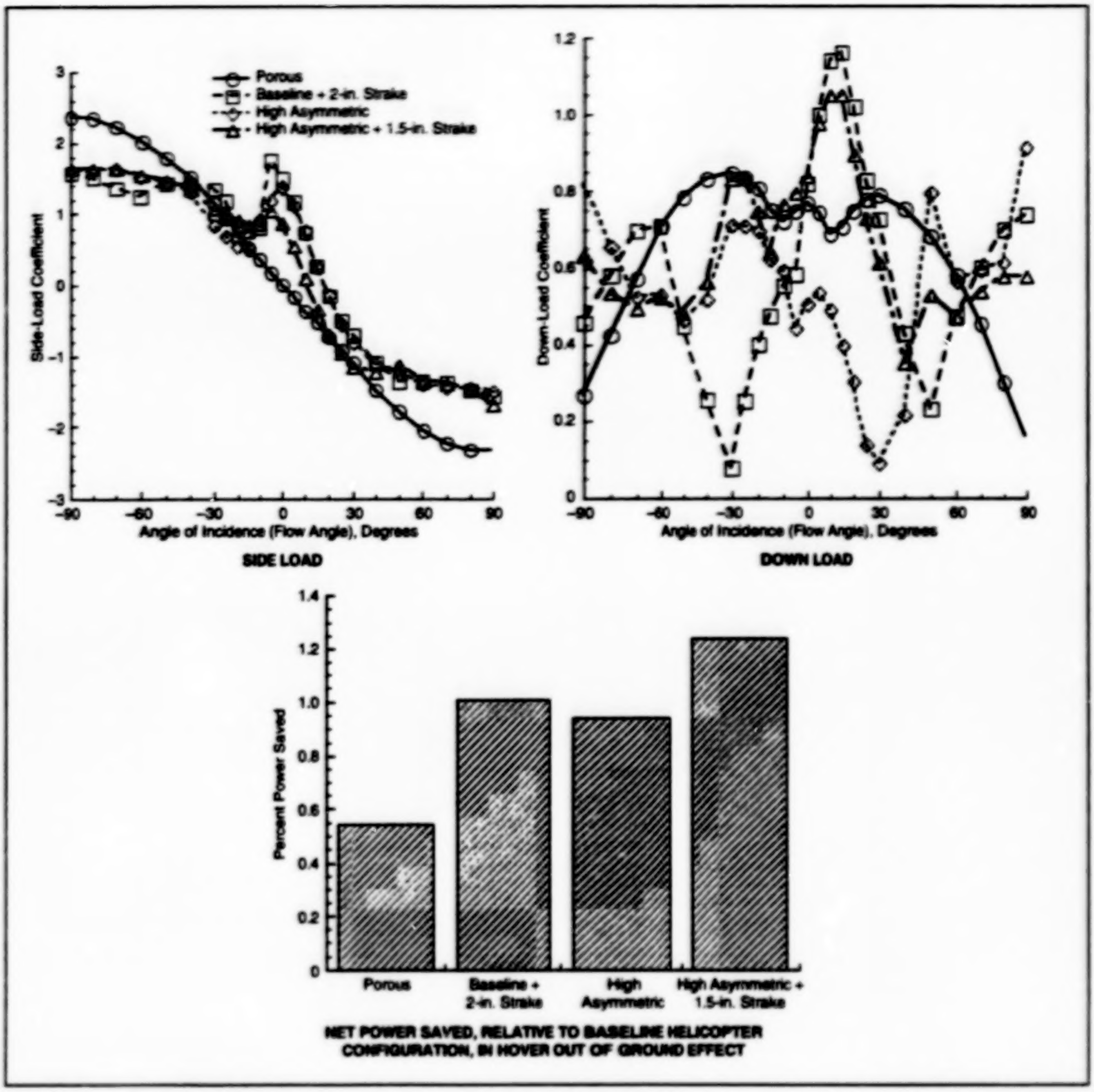


Figure 2. These **Preliminary Results of Experiments and Calculations** indicate that porosity could be useful for reducing adverse helicopter tail-boom loads.

schemes are possible, and vents could be used in conjunction with other devices, including strakes. The venting schemes include, but are not limited to, the use of porous material on all or parts of the boom connected to a specific plenum or open to the boom cavity, and the use of doors, grilles, slots, or other such openings. Further, it may be possible to capture a portion of the relatively high-speed downwash from the main rotor as it impinges on the upper surface of the boom and channel that flow to another area on the boom.

A wind-tunnel investigation was conducted to obtain some preliminary indications of the effectiveness of venting the boom for reducing adverse forces and moments. This study was conducted with two-dimensional tail-boom shapes in the 14-by-22-ft (4.3-by-6.7-m) subsonic wind tunnel at NASA Langley Research Center. The shape that was tested most extensively was representative of the tail boom of a UH-60 helicopter (see Figure 1) with the tail-rotor drive-shaft cover on. The aerodynamic forces, including the down load and side force, were measured at freestream dynamic pressures up to 30 psf (1.4 kPa), at full-scale Reynolds numbers, and at angles of incidence (wind azimuth angles) from −90° to +90° to simulate left and right cross winds. Calculations were performed, using the normal-force and side-force coefficients, to determine the trends of the aerodynamic forces on the boom of a full-scale UH-60 helicopter and to estimate the main-rotor and tail-rotor power needed to trim those forces in the presence and absence of venting.

The results indicate that passively venting a helicopter tail boom can alleviate some of the adverse side forces that are generated in hover and in sideward flight. There was found to be a mild penalty in increased down load that is partly attrib-

uted to the increased skin friction associated with the nonoptimal porous surface (a commercially available material) that was used in the experiments. It was found that for the same loading, it takes more power to overcome a side load than to overcome a down load because the tail rotor is much more heavily loaded and less efficient than is the main rotor. Therefore, the penalty in down load was found to be less than the beneficial reduction in side load. The overall result was found to be reductions in the adverse forces and the calculated power demand, similar to the reductions afforded by the application of strakes.

Other venting arrangements or more optimal porous material could reduce the down-load penalty while also alleviating the side force. Plots of the side-load coefficient (C_y) and the down-load coefficient (C_z) are shown in the upper part of Figure 2. Calculated trends in the power demand are shown in the lower part of Figure 2. Although the calculated trends in the power demand were found to vary widely among different configurations, the net result was found to be a reduction for the porous configuration, relative to the baseline solid configuration. Also, for the porous configuration, the character of the plots of C_y versus the angle of incidence was smoother, without the discontinuous nature and a less abrupt boom stall, as compared with that of the baseline solid configuration. The smoother characteristics of the porous configuration would result in fewer yaw-control disturbances during flight in gusty or turbulent air.

This work was done by Daniel W. Banks of **Dryden Flight Research Center** *and Henry L. Kelley of the U.S. Army Aeromechanics Laboratory at Langley Research Center. Further information is contained in a TSP [see page 1].*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Dryden Flight Research Center, Attn: Yvonne Kellogg, D-4839A, P.O. Box 273, Edwards, CA 93523-0273. Refer to DRC-98-96.

Conformably Stowable Canard

Low-speed performance can be improved without incurring a high-speed wave-drag penalty.

Ames Research Center, Moffett Field, California

An improved secondary wing system of the canard type has been invented to improve performance and increase efficiency of airplanes capable of flight at supersonic and high subsonic speeds. Canards, including small forward-mounted secondary wings, are used to increase the total wing surface areas of airplanes in order to improve their low-speed lift-to-drag ratios and trim characteristics. Although canards have been used on supersonic airplanes to increase low-speed performance, heretofore, the designs of canards have not provided for optimal high-speed performance and aerodynamic efficiency.

The present secondary wing system includes a single canard that can be pivoted about a vertical axis at its spanwise midpoint (see Figure 1). By such pivoting in conjunction with retraction or extension of fairings, the canard can be either (1) deployed to augment the lift, stability, and control of an airplane during lower-speed flight or (2) retracted conformally into the fuselage in order to minimize drag at higher speeds. The canard is equipped with leading- and trailing-edge control surfaces to enhance the aerodynamic performance of the airplane during use of the canard at low speed.

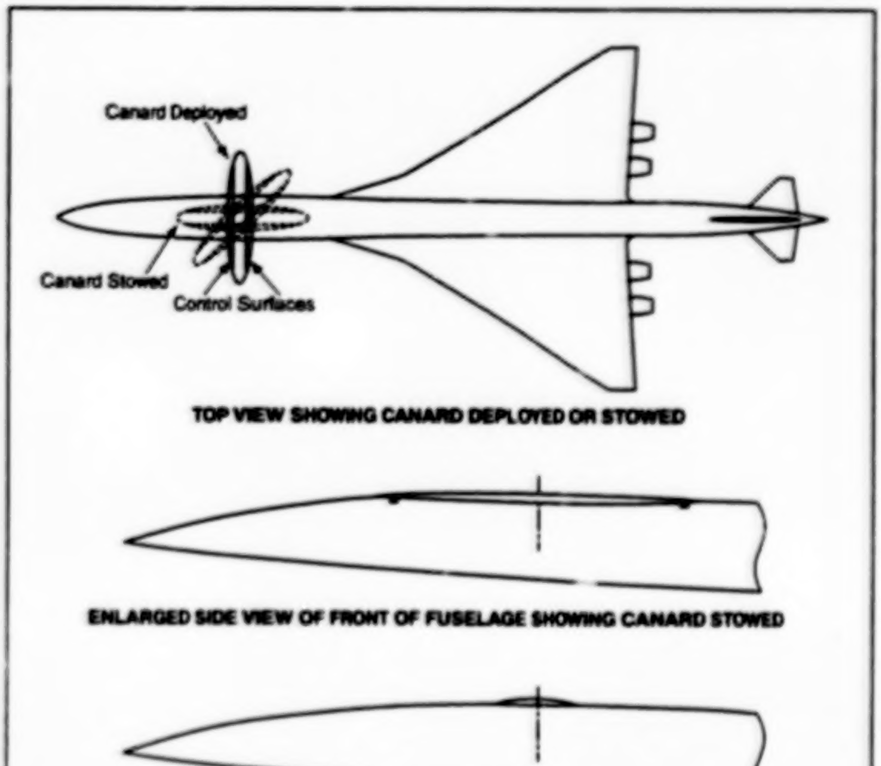


Figure 1. The **Canard Is Deployed** by rotating it so that its spanwise axis lies perpendicular to the longitudinal axis of the fuselage, and is stowed by rotating it so that its spanwise axis lies parallel to the longitudinal axis of the fuselage.

This invention is applicable to an airplane, the fuselage of which is area-ruled and includes a bulbous forward portion. A unique feature of this secondary wing system is that the secondary wing has a quasi-elliptical planform shape derived from an imaginary horizontal planar cut through an upper portion of the bulbous forward portion of the fuselage. The elliptical planform shape favors aerodynamic efficiency at low speed, thereby making it possible to reduce the engine power (and thus also noise) during low-speed operations, including takeoff, climb, and landing.

The lower surface of the canard is substantially flat as defined by the imaginary cut through the fuselage. When the canard is stowed, the upper surface of the canard (except at its edges) constitutes the surface of the upper portion of the fuselage

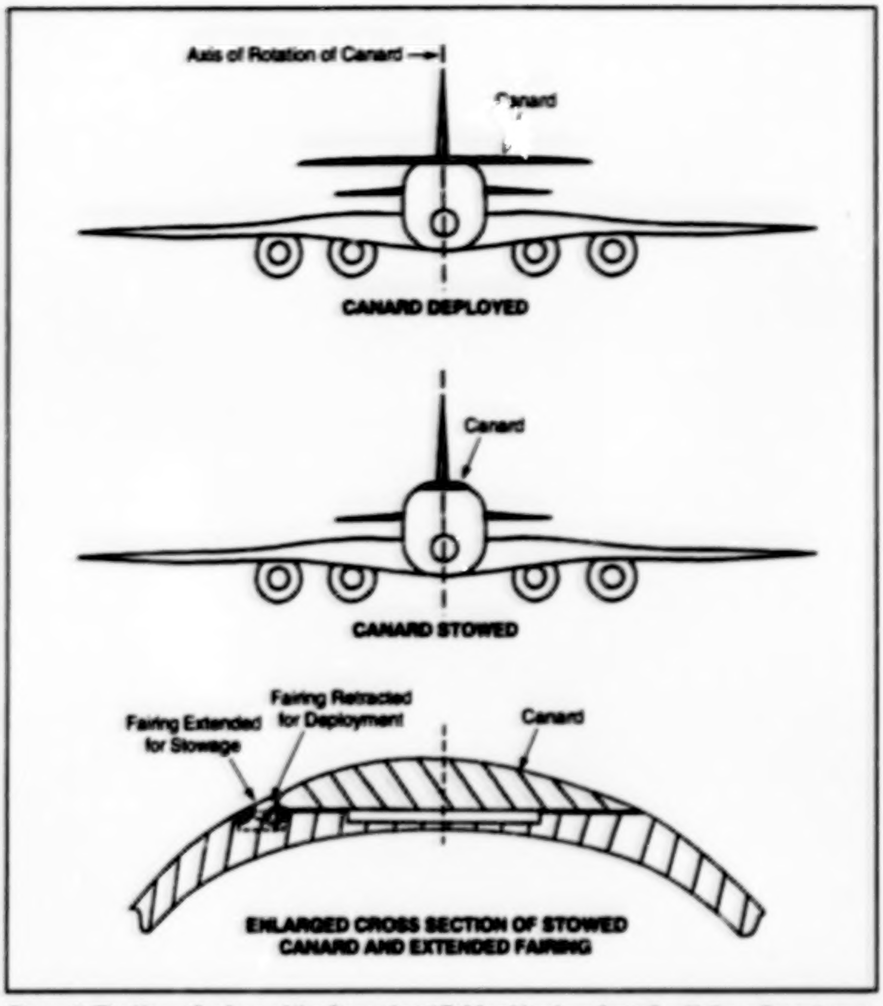


Figure 2. The **Upper Surface of the Canard and Fairing** blend conformally with the adjacent upper fuselage surface.

from which the canard planform and loft was derived. When the fairings are extended at the leading and trailing edges of the canard to complete the stowage of the canard, the combination of the upper surface of the canard and the fairings define a streamlined surface contour that blends smoothly with the surface contour of the rest of the fuselage (see Figure 2), thereby promoting aerodynamic efficiency in high-speed flight. The characteristic fuselage shape that results from designing according to the area rule makes it possible to incorporate a canard that can be used at low speed and conformally stowed in the fuselage without incurring significant wave-drag penalty at high speed.

The canard is connected to the fuselage by a ring-and-track mechanism, which includes (1) a submechanism for rotating the canard about a vertical axis for deployment or stowage as described above and (2) an actuated hinge submechanism that can be used to vary the angle of incidence of the canard when the canard is deployed. The design of this mechanism is such as to minimize its intrusion into the interior volume of the fuselage. The secondary wing system can include additional mechanisms for securing the tips of canard to the fuselage when stowed to prevent flutter and flutter-induced damage that could otherwise be caused by the aerodynamic loads that are present during high-speed flight.

This work was done by Brian E. Smith of **Ames Research Center**. *Further information is contained in a TSP [see page 1].*

This invention has been patented by NASA (U.S. Patent No. 5,992,796). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14122.

First-Order Theory of Control of Motion of a Crane and Load

Suitably modulated motion of the crane could prevent swinging of the load.

John F. Kennedy Space Center, Florida

A first-order mathematical model has been developed in a theoretical study of the dynamics of a load suspended by a cable from a crane that moves along a straight track. The model is the basis of a proposed method of computer control of the velocity as well as the position of the crane to minimize or prevent swinging of the load. (Traditionally, only the position of the crane is controlled; there is no engineering provision against swinging of the load.) Velocity and position control to prevent swinging would be highly desirable, especially in situations in which there are requirements for precise placement of large loads and/or the delays incurred in waiting for damping of pendulum oscillations of loads are unacceptable. Because most modern cranes are already controlled by computers and include position-indicating control subsystems, the implementation of this method of control would entail little or no additional equipment and thus should be relatively inexpensive.

The mathematical model describes the coupled motions of the crane head, cable, and load, with simplifying assumptions that (1) friction on the cable and load is negligible, (2) the mass of the cable is negligible compared to that of the load, (3) the load acts like a point mass, (4) the length of the cable remains constant during the controlled motion, and (5) the angle between the cable and the vertical is never more than a few degrees, so that the first-order pendulum approximation is justified. The basic equation of the model is

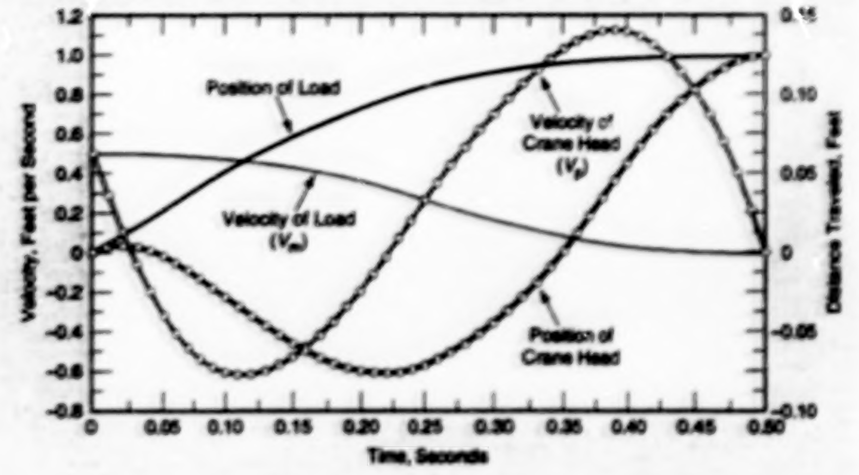
$$V_p(t) = V_m + \left(\frac{l}{g}\right)\frac{d^2V_m(t)}{dt^2},$$

where V_p is the velocity of the crane head (which can be controlled), $V_m(t)$ is the velocity of the load mass, l is the distance (approximately equal to the length of the cable) between the center of mass of the load and the point of attachment of the cable to the crane head, g is the gravitational acceleration, and t is time. Mathematically, the control prob-

lem for accelerating (or, equivalently, decelerating) the load without inducing pendulum oscillations is to choose a crane-head velocity function $V_p(t)$ such that the load velocity will be a desired function $V_m(t)$, subject to the boundary conditions that at the end of the acceleration and or deceleration interval, both the crane and the load must be at the same horizontal position and velocity and must not be accelerating.

Suppose, for example, that the crane head and the load mass are initially moving together at a constant velocity with the load mass directly under the crane head, and it is desired that the load mass be stopped smoothly at a given location. In principle, there are infinitely many velocity functions $V_p(t)$ that can produce this effect. Essentially all of them start by decelerating the crane head first. This causes the load mass to move in front of the crane head, so that the cable pulls back on the load mass, decelerating it. Then, after substantial deceleration by the load mass, the crane head is made to move forward faster than the load mass, moving back over the load mass and stopping the deceleration of the load mass just as $V_m(t)$ reaches zero (see figure).

There are many variations on this theme; in all of them, the crane head is made to move back and forth in order to make the cable exert acceleration and deceleration forces on the load mass and the crane head is repositioned to prevent the load mass from swinging or starting any other motion not desired. Of course, one should choose a desired $V_m(t)$ with acceleration and/or deceleration gentle enough that the $V_p(t)$ needed to obtain it is not so jerky and/or does not require so much precision as to lie outside the operational range of the crane motor and its control system.



The **Motions of a Crane Head and Its Load** suspended 3 ft (0.9 m) below the crane were computed for a case in which the initial velocity of the crane and load was 0.5 ft/s (0.15 m/s) and it was required to bring both the crane head and the load to a stop within a time of 0.5 s.

Some aspects of the theory remain to be addressed. In particular, it would be desirable to generalize the mathematical model to the cases in which the length of the cable changes during the controlled motion, the angle is large enough that the model must include the full nonlinearity of the dynamics, and/or the crane can be moved along either or both of two orthogonal horizontal axes. A further problem to be considered is that of the degree to which the position and velocity of the crane can be measured and controlled and the effect to which limitations in control degrade the desired motion.

This work was done by Robert C. Youngquist, James P. Strobel, and Stan Starr of I-NET for **Kennedy Space Center**. *Further information is contained in a TSP [see page 1].*
KSC-11942

Machinery

Books and Reports

42

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Hybrid Regenerative Water-Recycling System

A wastewater-recycling system contains biological and physicochemical water-treatment units. The system is suitable for use in environments in which clean water supplies are limited. Waste streams containing urine and washwater are purified into potable water with a recovery rate of 99 percent. The system includes a two-stage trickling-filter bioreactor, a reverse-osmosis unit, and a photocatalytic post-treatment subsystem. The first stage of the bioreactor reduces the concentrations of organic (carbon-based) compounds, while the second stage removes nitrogen compounds. The effluent from the reactor is sent to the reverse-osmosis unit, which passes 85 percent of the water and diverts the other 15 percent into a concentrated brine. Water is recovered from the brine by evaporation. Finally, the water is treated by ultraviolet light and titanium oxide for disinfection and for oxidation of any organic residue. The system can treat small amounts of very concentrated wastewater, without use of pretreatment chemicals, at low power consumption.

This work was done by Marybeth Edeen, Charles Verostko, and Mary Cleave of **Johnson Space Center** *and Nigel Packham of Lockheed. Further information is contained in a TSP [see page 1].*
MSC-22622

Thruster Based on Sublimation of Solid Hydrazine

A report proposes a small spacecraft attitude-control thruster in which the propellant material would be hydrazine that would be stored frozen until sublimed at the instant of use. From the upstream to the downstream end, the main components of the thruster would include a plug of solid hydrazine in a container, a rapid source of radiant heat (e.g., a laser diode or a flash lamp), and a heated-catalyst-and-nozzle assembly like that of a conventional hydrazine thruster. In operation, each pulse of radiant heat would cause a small amount of frozen hydrazine to sublime. The puff of hydrazine vapor thus generated would become chemically decomposed in the heated catalyst, and an impulse would be generated by the expansion of the puff of decomposition products in the nozzle. This thruster would be attractive for generating small impulses (impulse "bits") on command for precise maneuvering of a spacecraft that either remains below the freezing temperature of hydrazine (≈274 K) or that contains equipment to keep the hydrazine refrigerated.

This work was done by Larry Roe of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Subliming Solid Hydrazine Thruster," see TSP's [page 1].*
NPO-20540

Liquid/Vapor-Hydrazine Thruster Would Produce Small Impulses

A report proposes a liquid/vapor-hydrazine thruster for use in controlling the attitude of a small spacecraft. From the upstream to the downstream end, the thruster would include a tank containing liquid hydrazine, a fast liquid valve, a heated prevaporizing plenum, a fast gas valve, and a heated catalytic bed. In one mode of operation (the conventional mode), heat would not be supplied to the prevaporizing plenum; instead, liquid hydrazine would be fed directly to the heated catalytic bed. In another mode of operation, heat would be supplied to the prevaporizing plenum, and the gas valve would be opened in brief pulses to pass the hydrazine vapor to the heated catalytic bed to produce small pulses of thrust. The use of vapor (as compared with liquid) feed in the pulse mode would make it possible to generate smaller impulses, which are better suited for highly precise spacecraft maneuvers.

This work was done by Larry Roe of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Liquid/Vapor Millinewton Hydrazine Thruster," see TSP's [page 1].*
NPO-20541

Fabrication Technology

Hardware, Techniques, and Processes

4/6

Process for Polishing Bare Aluminum to High Optical Quality

India-ink polishing following single-point diamond turning yields superior aluminum optics.

Goddard Space Flight Center, Greenbelt, Maryland

A process for making precise, high-quality curved or flat mirror surfaces on bare aluminum substrates has been devised. The process consists of (1) diamond turning to establish the desired surface figure, followed by (2) a polishing subprocess that is mostly conventional except for the composition of the polishing compound. This process can maintain a surface figure accurate to within a peak-to-valley error of as little as 1/8 wavelength (at a wavelength of 6,328 Å) and can produce a finish characterized by a root-mean-square roughness of <8 Å. Hence, the process creates possibilities for the fabrication of precise scientific-instrument mirrors (see figure) that, because they could be made entirely of aluminum, would be lightweight, relatively inexpensive, and thermally stable over wide temperature ranges.

An Aluminum Mirror is produced to high optical quality using India ink and single-point diamond turning.

Because of the relative softness of aluminum, heretofore, there has been no way to polish bare aluminum to an optical quality adequate for precise scientific instrumentation. Under optimum conditions, diamond turning can be used to obtain a surface figure within an error of no less than about 0.5 wavelength and surface roughness of no less than about 50 Å on an aluminum substrate. To obtain higher optical surface quality, it has been necessary to deposit a thin coat of electroless nickel on a diamond-turned aluminum substrate, then conventionally polish the nickel coat. The disadvantages of this approach are that plating nickel onto aluminum is difficult and expensive, bimetallic thermal stresses can distort the optical surface of the mirror, and there is risk of polishing through the nickel coat in one or more spots. In the latter case, it is necessary to strip the entire coat, redeposit a new nickel coat, and begin polishing anew.

In both conventional practice and the present process, polishing involves the use of a lap that is coated with a polishing compound and liquid carrier and is moved semirandomly and repeatedly over the substrate surface. Conventionally, the liquid carrier is often water. The major distinguishing feature of the present polishing subprocess is that India ink (either alone or diluted with water) is used as both a polishing compound and the liquid carrier. (India ink has been used in the past in this way to polish metals, but not, until now, as an ingredient in an integrated diamond-turning/polishing process for finishing aluminum to precise surface figure and high optical quality.)

The present polishing subprocess consists of two stages. In the first stage, the diamond-turned surface is polished with a mixture of 0.25-μm diamond powder, distilled water, and India ink. In the second stage, polishing is started with pure India ink, and then the ink is slowly diluted with water. Polishing is continued until the desired specification is achieved.

The success of this process has been attributed partly to the carbon particles in India ink. These particles are small and hard enough to provide the correct action between the substrate and lap so as not to cause severe scratching or cold flow of the substrate. In addition, the liquid portion of the ink includes an oily base that acts as an excellent lubricant during polishing. After years of experimentation with known conventional polishing materials and combinations thereof, India ink is thus far the only material known to be effective for polishing bare aluminum.

This work was done by James J. Lyons and John J. Zaniewski of **Goddard Space Flight Center**. *Further information is contained in a TSP [see page 1].*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 1]. Refer to GSC-14147.

External Adhesive Pressure-Wall Patch

A hole in a pressure wall can be patched, without need for previously installed fasteners.

Marshall Space Flight Center, Alabama

A mechanical device has been developed for applying an adhesive patch, from the outside, to the wall of a spacecraft module that has lost pressure because of penetration by a meteoroid or a piece of orbital debris. This device will make it possible to seal and re-pressurize the affected module during space flight. Devices identical or similar to this one might also prove useful in the repair of other pressurized bodies and similar objects, including gas and oil pipes and ship hulls, for example.

The device includes a patch frame, which is moved toward the hole to be patched from the exterior side of the damaged wall by use of handles. The device also includes a flexible outer sealing ring that becomes molded against the wall.

Another component of the device is a probe that includes a right-hand-threaded shank and is equipped with an assembly of spring-loaded sprags at its penetrating tip.

The probe is inserted in the hole. When the probe has passed through the hole in the wall to the interior side, the sprags spring outward. Next, the probe is turned counterclockwise to draw the sprag assembly toward the patch frame; as a result, the sprags are forced against the inside edge of the hole in the wall. As the probe continues to turn, the sprag assembly stays in place and the flexible outer sealing ring on the patch frame becomes pushed against the wall on the outside; this action creates a seal between the patch frame and the wall.

Next, the volume enclosed by the patch frame, wall, and outer sealing ring (called the "patch body volume" for short) is filled with a liquid adhesive sealant material to create a permanent seal and strong adhesion between the patch and the wall. The adhesive sealant is injected into the patch body volume through quick-connect/quick-disconnect fittings that are similar to automotive grease fittings and that are located in several positions on the patch frame. Although the patch is not a substitute for the loss of structural strength caused by the penetration, the adhesive bond between the patch frame and the wall is strengthened by an adhesive-interface plate on the patch frame: as the adhesive flows into the patch body volume, it flows onto and around hooks that protrude from the adhesive-interface plate. Once the adhesive hardens, the patch is held in place against the tensile loads induced by re-pressurization of the interior of the spacecraft module, pipeline, or other volume enclosed by the wall.

Success in the use of the patching device does not depend on the prior installation of structural fastening devices on the wall to be repaired. Another advantage of this device is that its flexible outer sealing ring makes it adaptable to a variety of external wall configurations, structures, and radii.

This work was done by Joel Williamsen, Kathryn Horton, and Bruce Weddendorf of **Marshall Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov. Refer to MFS-31173.

Mathematics and Information Sciences

Hardware, Techniques, and Processes

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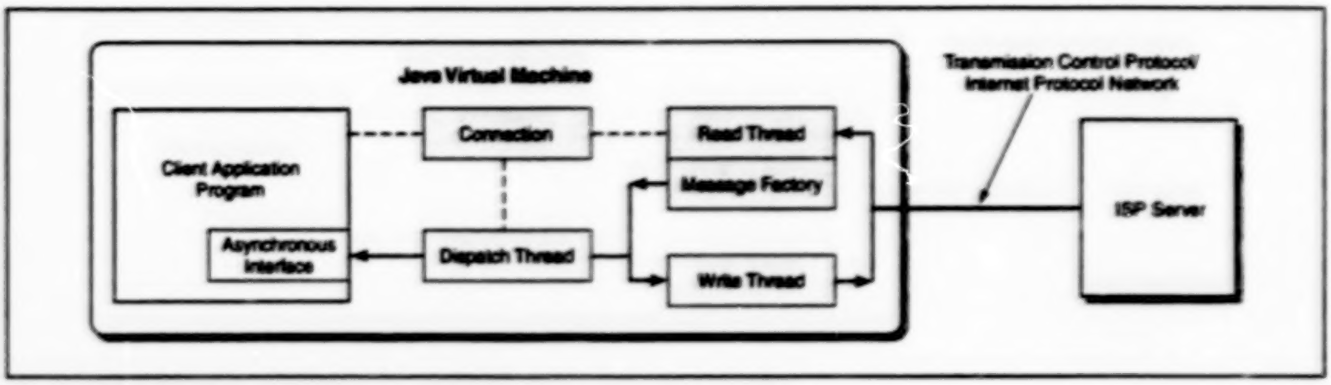
Java Implementation of Information-Sharing Protocol

The Java-language ISPresso software enables real-time access to mission data via home and office personal computers.

Lyndon B. Johnson Space Center, Houston, Texas



The Functional Elements of ISPresso are established within a Java virtual machine.

Johnson Space Center's (JSC's) growing operations community requires new ways to distribute and process mission information. The Mission Control Center uses flight-control application programs based on an information-sharing protocol (ISP) to process and distribute real-time mission telemetry, trajectory, and computation data. ISP application programs provide multiple users synchronous, rapid access to mission data and programs. The ISPresso ISP software package is designed in Java, which is rapidly becoming the language of choice because of its ability to work on almost any platform. ISPresso plays a substantial role in the remote-access platforms now being implemented for space-shuttle and space-station operations and is used for Hubble Space Telescope operations. The portability of ISPresso enables deployment of mission-data-processing application programs to desktop computers and makes it possible to package application software for convenient access through web browsers. Such accessibility will prove useful in many additional process-control settings, from powerplants to all types of manufacturing.

Current ISP client software libraries are written in the C computing language for Unix; consequently, all telemetry application programs must also run on Unix platforms. The advantage afforded by Java is that, once written, a Java application program can run anywhere a compliant Java virtual machine (VM) is available. Because ISPresso is written in Java, it can run on any platform that includes a Java VM.

ISPresso is a product of a complete redesign and rewrite of ISP client software libraries to take advantage of the easy-to-use, synchronous (threaded), Internet-friendly nature of Java for creating ISP client programs. The ISPresso library consists of seven Java software packages. The essential functional elements of ISPresso are shown in the figure. The Read Thread, Message Factory, and Write Thread constitute the primary interface to the ISP server. They provide generic input/output and event-based message-passing and specific message-passing. The Connection and Dispatch Thread functions are performed by the ISP client interface software package, with ISP updates encapsulated into the Value, Message, and Status classes. The Connection function includes mode control over the other functional elements, as indicated by the dashed lines. Solid lines denote data flow within ISPresso. The Dispatch Thread delivers updates asynchronously to the client application program via the Observer interfaces in the ISP client interface software package.

The portability of Java gives ISPresso several advantages over the C/Unix version of ISP:

- Unlike C/Unix ISP application programs, ISPresso can run from desktop computers.
- Unlike C/Unix application programs, ISPresso application programs can run on desktop personal computers or on the JavaStation — a Java-only platform that is configured entirely from servers and therefore costs almost nothing to maintain.
- Although C/Unix ISP application programs can usually be transferred from one system to another with minimal rework, certain transfers do necessitate spending significant time and effort to restore compatibility. Developers of ISPresso code need to produce and maintain only one set of code for all platforms, inasmuch as any computing system with the Java VM accepts the code readily.
- Java is becoming a language of choice for the software industry; the number of Java software products will soon surpass that of software products in the C++ language and will likely eclipse that of programs in the C language. Java VMs are distributed widely via Java-enabled web browsers. Universities are adopting Java as their standard "teaching language" for computer-science courses. The number of software tools available, the variety of types of products, and the number of qualified programmers will make it easier and more economical to equip and staff development teams for Java-based software products than for C/Unix software products.

This work was done by James C. Thompson and Steven P. Weismuller of United Space Alliance for **Johnson Space Center.**
MSC-22942

Electronic Bulletin Board Publishes Schedules in Real Time

Real Time Schedule Publisher (RTSP) is a computer program that generates a report of the current schedules of as many as about 25 users within an organization. The report is refreshed every 5 minutes and displayed in a common area on a flat-panel computer monitor that serves as an "in/out" bulletin board. The report is displayed in a five-column tabular format and

includes color-coded legends that describe the status (with respect to availability) of each user. Each row of the table reflects a single event for a single user; the five columns represent, respectively, the name of the user, the event start time, the event end time, the location, and the subject. The display also includes the current date, day of the week, and time. In addition to the common display, an interactive view of the scheduling information is available, through a standard web browser, on any desktop computer connected to the organization's computer network. The interactive view provides an interface for administering users' accounts. RTSP is based on the active-server architecture of the Windows NT Server operating system and is integrable with similarly based commercial-off-the-shelf scheduling programs.

This work was done by James Alberti of **Kennedy Space Center** *and James B. McSorley, Roger B. Right, Jeffrey S. Hixson, David S. Metcalf, and Michael Hallberg of RWD Technologies, Inc. Further information is contained in a TSP [see page 1].*
KSC-12095

Life Sciences

Hardware, Techniques, and Processes

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Measurement of Stresses and Strains in Muscles and Tendons

Small, electrically and chemically neutral sensors would be implanted surgically.

NASA's Jet Propulsion Laboratory, Pasadena, California

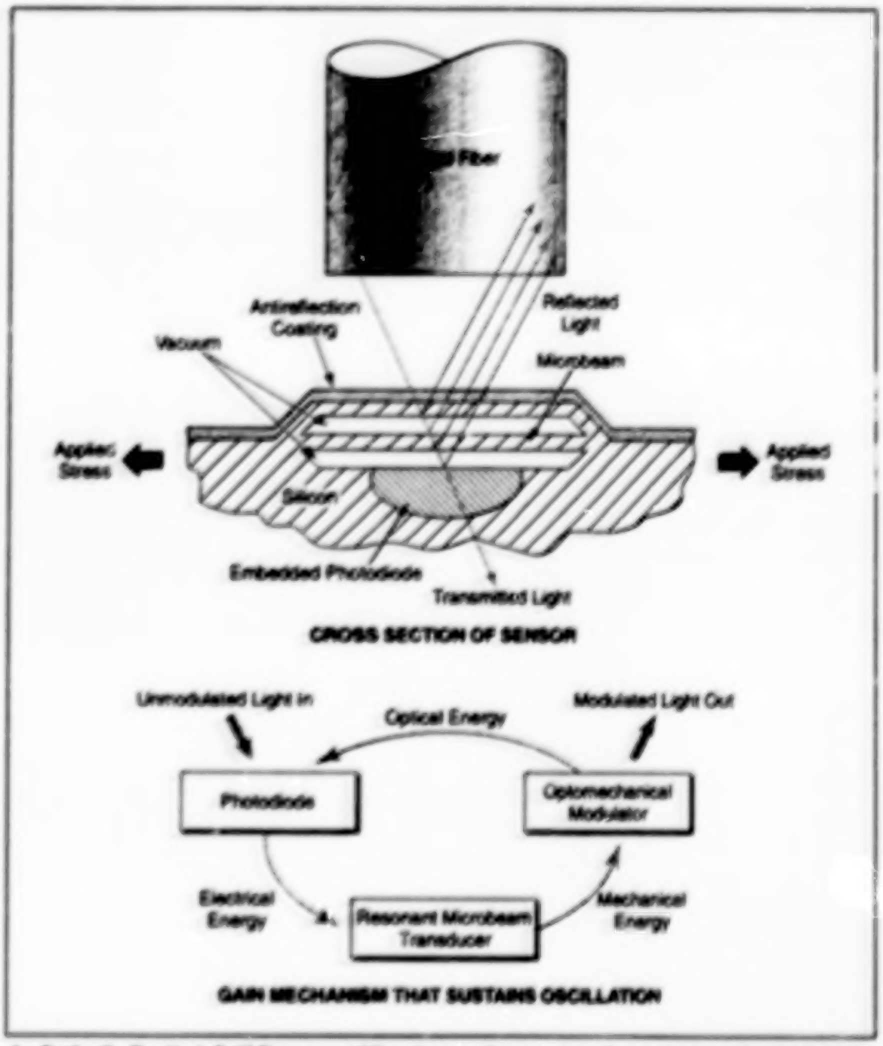
Miniature fiber-optic-coupled sensors based on optically excited, self-resonant microbeams are being developed for measuring stresses and strains within muscle fascicles and tendons. These sensors could be used in medical and biological research on humans and other animals, or to obtain data for the design of lifelike robots.

Each sensor has typical dimensions of about 1 by 1 by 0.1 mm. These dimensions are suitable for surgical implantation in muscle and tendon tissues; these dimensions are also comparable to diameters of cores of multimode optical fibers, making the sensors amenable to fiber-optic coupling.

The figure depicts the main transducer portion of a sensor of this type and its mode of operation. The sensor contains a microbeam that has been micromachined as an integral part of a polysilicon housing. The microbeam is suspended in a vacuum cavity in the housing, over an embedded photodiode. The microbeam vibrates at a resonance frequency of the order of a megahertz, with a resonance quality factor (Q) of about 10^5.

The sensor exploits a unique gain mechanism that involves the exchange of optical, electrical, and mechanical energy during each cycle of oscillation: When the sensor is irradiated with infrared light via an optical fiber, the electric charge photogenerated in the diode electrostatically deflects the beam, setting the beam into vibration at its resonance frequency. Because the microbeam-and-cavity structure constitutes a Fabry-Perot interferometer, vibration of the beam modulates the transmitted light, thereby modulating the photovoltage and thereby, further, sustaining the oscillation.

Vibration of the beam also modulates the infrared light reflected back along the optical fiber. The reflected light is converted to a quasi-digital pulse stream by a photodetector, and the pulse-repetition frequency (equal to the frequency of vibration) is measured to obtain an indication of the physical quantity of interest (stress or strain).



An **Optically Excited, Self-Resonant Microbeam** vibrates when illuminated by infrared light via an optical fiber. Light reflected back along the fiber is modulated at the vibrational frequency, which varies with the stress applied to the silicon housing.

For measuring stress or strain, the microbeam and housing must be configured such that the resonance frequency varies with longitudinal stress applied to the housing. The stress could be applied to the sensor via fibers or ribbons attached to a tendon. If the sensor is to be used to measure strain in a tendon, then both fibers or ribbons must be nonextensible and are attached to the tendon. If muscular tension is to be measured, then both fibers or ribbons must be nonextensible and attached to the loose ends of a severed tendon. If muscle extension/retraction is to be measured, then one fiber or ribbon must be nonextensible while the other is extensible by a known amount.

This work was done by James Weiss and Frank Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

NPO-20464

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